# TRAFFIC SAFETY

# IMPROVEMENT STUDY

## VOLUME I

prepared for

CITY OF BOZEMAN
1883
GALLATIN CO. MONTANA

prepared by

MARVIN & ASSOCIATES
Traffic, Transportation & Civil Engineers

# TRAFFIC SAFETY

# IMPROVEMENT STUDY



PREPARED FOR

## CITY OF BOZEMAN

PREPARED BY

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# INTRODUCTION

## STUDY PURPOSE

The City of Bozeman, in an effort to reduce or otherwise alleviate problems at accident cluster sites on the City street system, retained the Consulting Engineering Firm of Marvin & Associates to perform a traffic engineering study. The purpose of this study was to identify accident cluster locations, collect and analyze pertinent data, make short and long term safety improvement recommendations and establish a priority list of improvement projects.

Other studies using similar methods have been completed for Montana counties with the technical and financial assistance of the Montana Department of Justice, Highway Traffic Safety Division. The intent of the Highway Traffic Safety Division in sponsoring studies on county roads was to reduce accidents on county road systems and to establish an awareness of accident reduction measures so that a continuation of the program could be established within each county. In 1991, Highway Traffic safety shifted its emphasis to city street systems. The first two studies, completed in 1991, validated the analysis methods as applied to city street systems and this study represents a continuation of these efforts.

Since most major cities in Montana have traffic engineers or technicians on staff and are benefited by other safety programs, the intent of the safety improvement study is somewhat different than those completed in Montana counties. Much of major urban area street systems are designated as Federal Aid Routes. The classifications range from Primary Highways to Federal Aid Urban streets. These streets are usually urban arterials and collectors which have high traffic volumes. Monitoring accident data and traffic volumes; developing improvement projects; planning new facilities; and maintaining the system, is usually handled by the City and State. Programs such as the TSM Element of the Transportation Planning Process and the Montana Department of Transportation's Safety Program adequately cover most of the safety problems within Montana's major cities. Day-to-day operations

on the street system cover accident problem areas as they are brought to the attention of the city staff through citizen complaints or police requested investigations. Thus, this study is focused on those locations which may not be included in any of the formal State or City programs. Most of the accidents sites are on streets which do not fall under federal aid classifications and are commonly known as "Off-system" streets. Some of the study sites may be at locations that the City has implemented controls in the past, but have defied efforts at improving safety. The majority of sites are usually low volume streets which have had minor, but consistent accident problems. Because of a low number of accidents per year, these locations are not readily recognized as accident cluster sites. When subjected to intense analysis, as contained in this study's methods, large benefits from simple inexpensive improvements can be recognized. Thus, the purpose of this study is to identify accident cluster sites on city streets; recommend improvements; prioritize site improvements; and introduce cities to the methods used in this type of analysis.

The methodology used in this study, which primarily serves as the basis for the analysis, can be found in report *No. FHWA-RD-77-83 "Identification of Hazardous Locations"*. Refinements to the FHWA report made by *DCA Project No. 79-04-01-01* and subsequent county studies throughout the state, are also incorporated within this report. The methodology used to establish priority rankings is explained in the Benefit/Cost Ratio section of this report and is tailored specifically to the City of Bozeman's unique requirements.

Traffic safety improvements contained within this report will qualify for the Montana Department of Transportation, Off-system Safety Funds. Because of this, priorities and funding obligations are specifically tailored to MDoT requirements. Upon approval by the City of Bozeman, this report should be submitted to MDoT as justification for Off-system Safety fund allotments.

## REPORT ORGANIZATION

The initial section of this report contains narratives describing the accident cluster site locations, characteristics of the city street system, study methodology, results of the hazard index analysis for all of the sites, explanation of the improvements recommended, priority index calculations, an implementation schedule and recommendations for continuation of the program in future years. Special attention should be given to the Site Characteristics and Explanation of Improvements sections, since specific traffic safety information for the Bozeman street system is presented in these sections.

Site specific data can be found within the individual site sections following the main body of this report. Site specific sections contain brief narratives regarding site conditions, observed problems, and recommendations. Also included is an accident summary page, 35mm pictures of the site, and supporting information as required.

A great deal of computer generated data was printed and reduced for inclusion on the existing condition and short term improvement sketches. The availability of pertinent data on the same page as the sketches hopefully aids in comprehension of the problem identification and improvement benefits. The short term plan sketches can also be used by the MDoT to verify the traffic control device items eligible for funding through their program. These sketches, being too voluminous for inclusion within this report, are bound separately as a plan packageand titled "Volume II". Any references to existing conditions or short term improvements within this report can be found in the that document. The 11"x17" plan sketch book can also be used by the City Street Department in the future, for actual implementation of most improvements.

The site specific sections of this report are numbered according to their priority ranking as indicated in the site location section of this report. Twenty (20) sites are included in this project, as per the contract budget. Some of the sites were located in close proximity along single streets. In addition, other sites identified during

the screening process indicated that some streets have accident problems at almost every intersection and significant numbers between intersections. At these locations a general evaluation of the corridor was completed. In this case, several corridors have been identified which were not specifically addressed within the transportation plan currently being completed.

Olive Street, from Willson to Bozeman Avenue, has a high accident rate. Most of the intersections included in this corridor are contained within specific study site evaluations and general corridor improvements are contained within the site analysis sections of this report.

North Fifth Avenue, from Mendenhall to Tamarack Street, has a high number of accidents at most intersections within this corridor. While individual intersection characteristics play a large role in the accident experience, there is a common situation which exists along this corridor which is further discussed within the main body of this report.

Local streets and intersections on the east side of Montana State University suffer from extremely high accident rates. Because these intersections are part of a larger access problem, this area is treated as a corridor evaluation and specific discussions with regard to this corridor can be found in the corridor section of this report.

# SITE CHARACTERISTICS

## SITE LOCATIONS

The map on the following page (Figure 1.) shows the twenty accident sites numbered according to their respective priority numbers. Table 1., below, is a listing of site numbers corresponding to the site locations:

### TABLE 1. LIST OF STUDY SITES

| PRIORITY SITE NO. | INTERSECTION STREETS | |
|---|---|---|
| *1* | *STORY* | *FIFTH* |
| *2* | *HAYES* | *THIRD* |
| *3* | *CURTISS* | *TRACY* |
| *4* | *OLIVE* | *SEVENTH* |
| *5* | *BABCOCK* | *YELLOWSTON* |
| *6* | *LAMME* | *FIFTH* |
| *7* | *PEACH* | *BOZEMAN* |
| *8* | *ARTHUR* | *THIRD* |
| *9* | *KOCH* | *THIRD* |
| *10* | *VILLARD* | *FIFTH* |
| *11* | *TAMARACK* | *FIFTH* |
| *12* | *OLIVE* | *TRACY* |
| *13* | *OLIVE* | *BLACK* |
| *14* | *VILLARD* | *TRACY* |
| *15* | *MENDENHALL* | *TENTH* |
| *16* | *BEALL* | *FIFTH* |
| *17* | *OLIVE* | *BOZEMAN* |
| *18* | *HAYES* | *FIFTH* |
| *19* | *BEALL* | *TRACY* |
| *20* | *GARFIELD* | *WILLSON* |

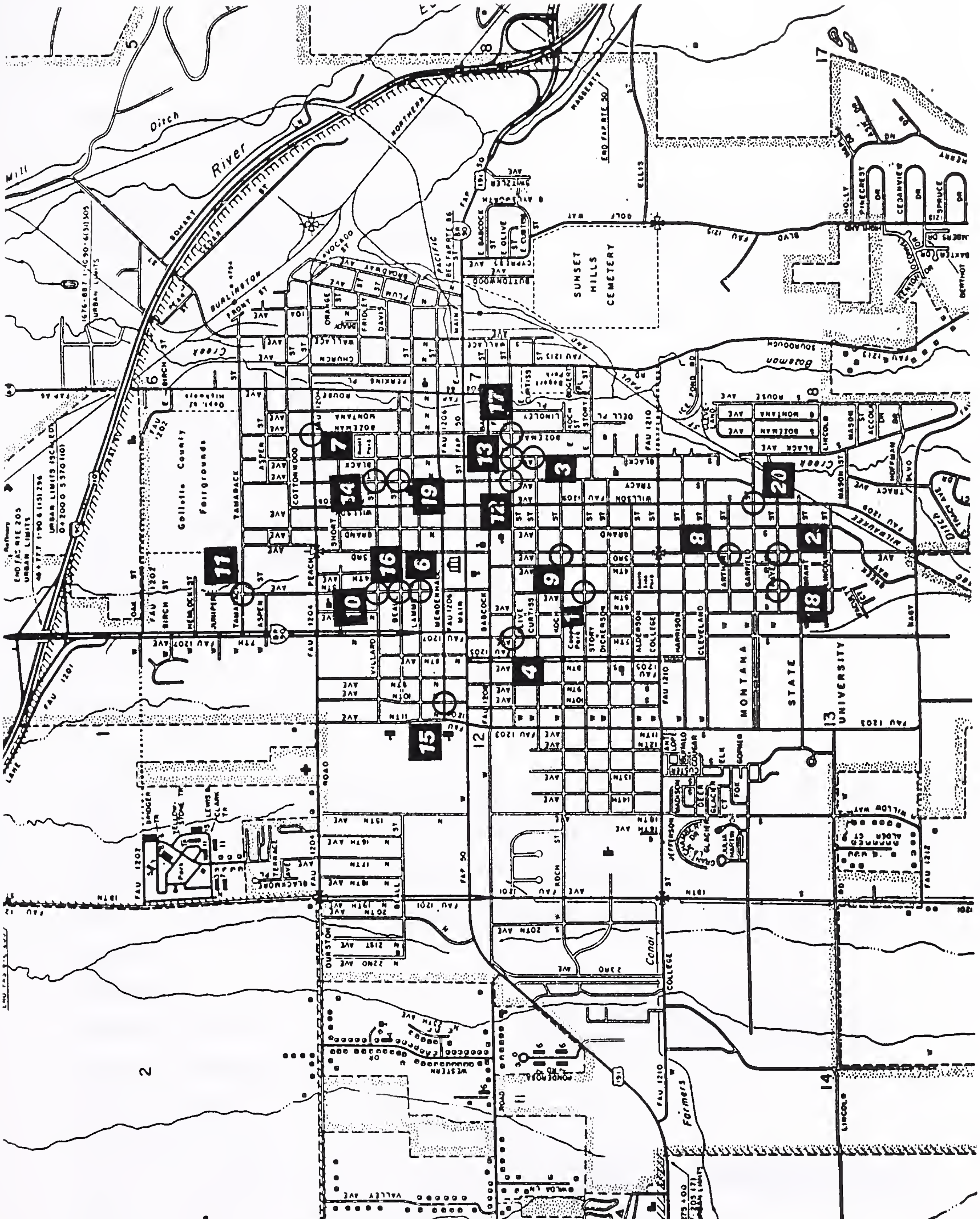


FIGURE 1. SITE LOCATION MAP

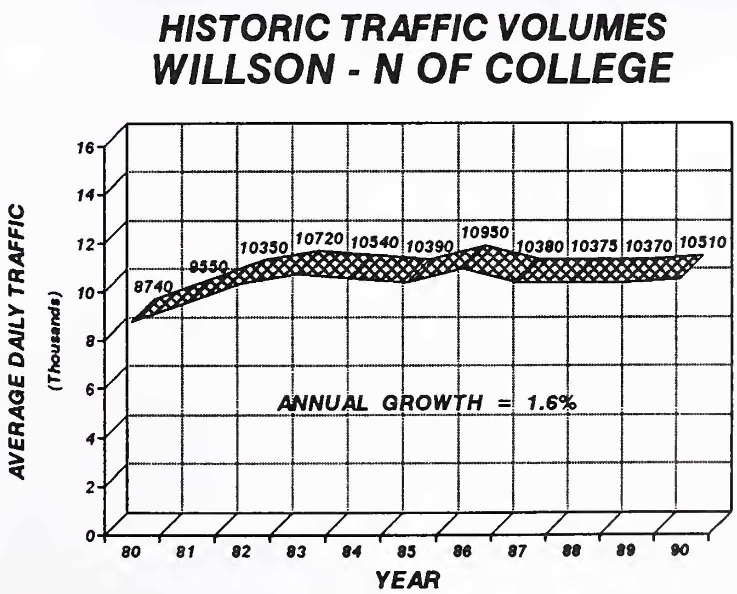
## SYSTEM CHARACTERISTICS

**Traffic Volumes** - All of the accident sites are located in a completely urban environment on relatively low volume streets. The highest traffic volume at any site is approximately 11,200 vehicles per day entering an intersection, while the lowest volume is approximately 700 vehicles per day entering. The average of all sites is approximately 3,800 vehicles per day entering. Average Daily Traffic (ADT) on all of the streets involved is approximately 1,800 and ranges between 10,600 and 150. The City of Bozeman has a continuous counting program and numerous past traffic counts were available at or near the study sites. The Montana Department of Transportation does not have a permanent count station in Bozeman. Therefore some traffic variables had to be estimated. Information taken from these count stations and estimated monthly variables were used to develop factors in estimating ADT's at the study sites.

### Historical Factors

Data provided by the Montana Department of Transportation indicated that traffic volumes on city streets have remained fairly constant over the past four years. Within the past year, traffic volumes have begun to increase at a number of locations. Data from those stations provides general, long range trends in traffic growth.

**Figure 2.** illustrates traffic growth on Willson Avenue, which is representative of most city streets within the past decade. Generally, traffic is growing at an annual rate of approximately 1.6 percent.

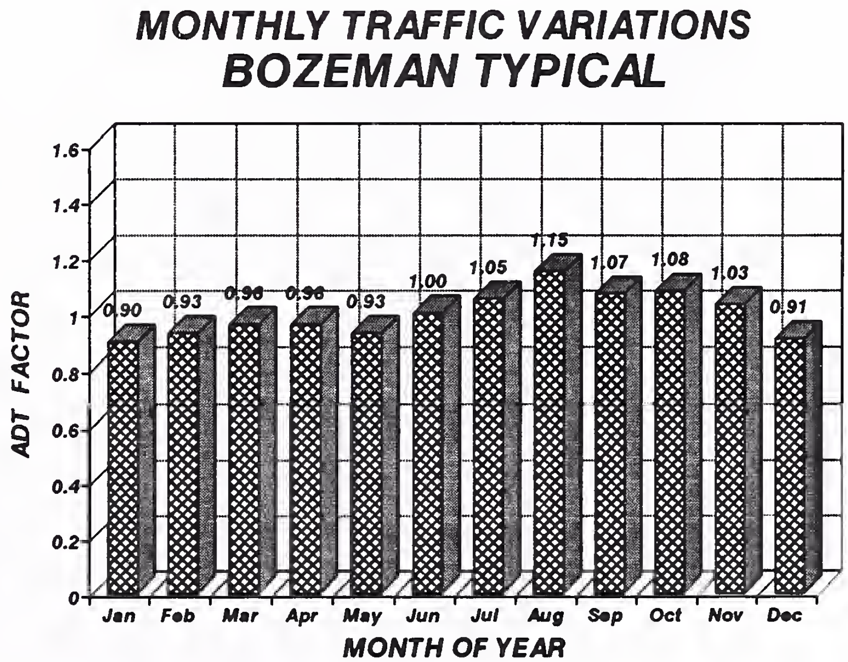


## Monthly Variations

A key factor in estimating average daily traffic is the month of the year. Traffic tends to vary significantly depending on the weather, seasonal economy, school sessions and various other reasons. Monthly variations provide an accurate reflection of seasonal conditions.

**Figure 3.** illustrates monthly traffic variations for arterials and collector streets in similar Montana urban areas. This data is an average of similar permanent count stations extracted from MDoT's permanent count station records.

This indicates normal variations between months of the year. August is the highest volume month, with approximately 115% of average monthly traffic. January is the lowest traffic month with ADT's being about 90% of the average month.

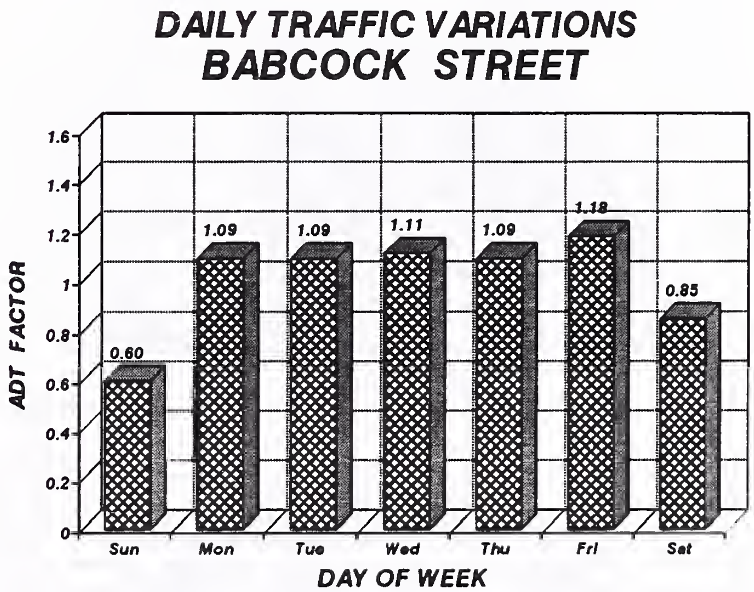



A permanent count station in Missoula weighed heavily in these averages because of similar student populations.

## Daily Variations

Traffic volumes vary significantly according to the day of the week and play an important role in estimating average daily traffic. Factors derived from extended traffic counts are not usually as reliable as monthly or seasonal factors due to the smaller time frame. Special holidays and events tend to skew daily variations. As an example, Monday holidays tend to have lower traffic than normal while the following Tuesday has higher than normal traffic.

**Figure 4.**, right illustrates daily traffic variations in Bozeman. This data was extracted from City counts at on Babcock Street.




The highest traffic day of the week is Friday, with 118% of average daily traffic. The lowest traffic day is Sunday, with only 60% of ADT. The remaining weekdays are fairly consistent at 109 to 111% of ADT.

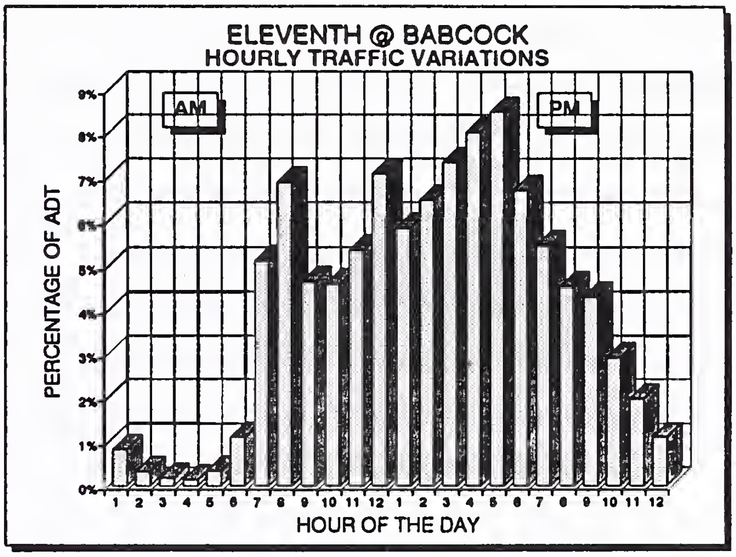
These daily variations compare closely with most streets within the urban areas of Montana and the Babcock counts appear to be fairly representative of most Bozeman streets.

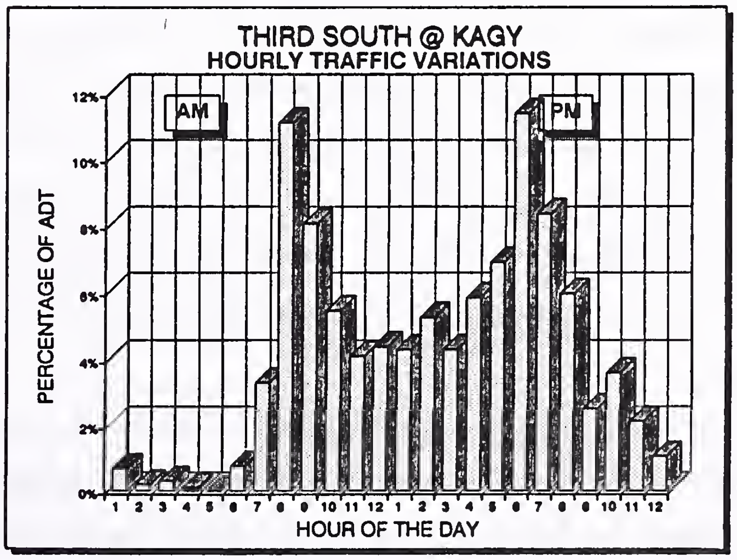
## Hourly Variations

Variations in traffic volumes by time of the day is highly predictable since there is usually no significant differences from one weekday to the next, at any one location. However, differences between various types of streets and locations can be vastly dissimilar. Twenty four hour machine recording counts on the same or similar streets are necessary to accurately estimate ADT's from shorter period counts.

**Figure 5.**, right, presents hourly traffic variations on Eleventh Avenue and on Third South. These are only two of numerous hourly count summaries prepared from data provided by the City of Bozeman.

Both graphs have different shapes. Eleventh represents most streets within the core area of Bozeman, while Third South represents mostly a commuter route and, thus the morning peak is similar to the afternoon peak.



**Street Characteristics** - The Bozeman city street system is laid out on a grid system with only slight variations in orientation. Most of the streets which vary from the north-south and east-west grid lie on the fringe areas of the city. Most of the study accident sites lie within the standard grid pattern.

Montana State University, on the southern end of Bozeman, has created an ever increasing disruption in the street grid continuity. As the university grew in the past, it became necessary to terminate streets within the city grid system. Future plans for the university include closure of additional streets. Since the university is a major traffic generator within Bozeman, traffic operations on the Bozeman street system are closely related to its existence.

As Bozeman grew, strip development occurred along the major highways through town. Main Street, a primary highway and N. Seventh, a former secondary highway currently provide primary access to Interstate 90 and are heavily lined with commercial properties. The city street system is somewhat disjointed by these streets and in some ways act more as a traffic barriers than as an integrated part of the street system. Heavy traffic volumes and some offset intersections along Main Street and N. Seventh impede safe and efficient traffic flow along intersecting street facilities. Heavy circulation and misdirected through traffic occurs on parallel streets in many areas.

Another distinguishing feature of the Bozeman street system is narrow right-of-way and street widths. Most of the older sections of town have streets with rights-of-way at 60 feet or less. Street widths average approximately 36 feet and there are many streets that are 30 feet or less in width. Considering the heavy on-street parking demand within Bozeman, streets appear to be confining and difficult to drive, comfortably. In addition, building setbacks on most lots are not sufficient to provide minimum sight distance requirements at uncontrolled intersections.

Physical characteristics of the streets are typical of most western cities. There is a mixture of old and new roadway design standards and access control. The majority of street surfaces could be classed in a poor to good category. In only a few cases, at the study sites, are the street surfaces in less than ideal condition.

Another common observation at local intersections was the roadside environment relating to trees, hedges and fences within in the intersection sight triangle. There were many areas where vegetation was over-grown to the point of creating obvious sight distance problems. Wherever stop signs were present, there was an obvious attempt to keep tree branches trimmed near the stop sign, but not on trees in advance of those signs. At other locations, tree trunks in the boulevard areas are so large that they sometimes create an intermittent sight restriction which may be related to some of the angle accidents. These type of blind spots can sometimes be more hazardous than a large imposing sight restriction because motorists are not consciously aware of the brief loss of sight.

**Parking** - A common problem observed at some of the study sites, involved lack of parking controls near intersections. While many of the sites have signs and and yellow curb marks, most of the local residential streets do not. This is entirely understandable, since it is very costly to mark every intersection when the majority of the time there are no apparent problems. Even when an accident problem appears, it is very difficult to attribute it to a mobile sight restriction. Only when changes in traffic volumes or parking habits occur do accident problems start to appear.

Enforcement of parking restrictions, when marked, is also critical to safe traffic operations. At several of the study sites vehicles were parked in restricted zones and no tickets were issued even when police were observed in the area.

Parking demand obviously exceeds supply within Bozeman. The university area has the most obvious problems, but significant on-street parking was noted in all areas of town. Since parking operations typically conflict with traffic operations, higher on-street parking demand creates a lower level of safety and efficiency on the street system.

**Drivers & Vehicles** - Bozeman drivers are typically slower and less aggressive than in other major Montana cities. Beside the fact that Bozeman is a smaller city with a less pressured life style, it is apparent that physical conditions of the street

system also contribute to less aggressive driving habits. Minimum intersection sight distance, narrow streets and heavy on-street parking all contribute to lower speeds and less aggressive driver behavior.

**Traffic Control Devices** - No traffic control devices other than street name signs were present at a majority of the study sites. At those sites which had some degree of traffic control devices, the applications range from street name signs to regulatory signs. Most of the signs and markings were applied correctly according to the Manual on Uniform Traffic Control Devices (MUTCD). Street signs appear to be in good condition at almost all of the sites. All study locations had street name signs but they were not mounted in consistent locations. Lack of such signing can become a major safety problem for motorists not familiar with Bozeman. In this situation, a large portion of the drivers cognitive powers are directed toward navigation. When there is little positive guidance provided, critical driving mistakes can be committed because little conscious ability remains for the other varied driving tasks.

Some damaged and faded signs were noted throughout the city. While not a very large percentage of total signs fall into that category, it is important to replace signs which become ineffective. The City of Bozeman, if it has not already begun, should begin developing a complete sign inventory and management system. Through this system, signs are replaced on a priority basis as budget allows. It is recommended that the City develop a program which allows all signs, regardless of priority, to be replaced after a maximum period of time in the sign's life.

There are numerous traffic signal installations within the City of Bozeman. Most of those signals are on the Federal Aid System. Several problems could be cited with some of the On-system signal installations. The most significant problems appear to be inadequate street geometry, lane control, phasing and coordination. There are also many intersections within Bozeman which obviously warrant signals.

## Traffic Accidents

Traffic accident characteristics for all of the Bozeman study sites are summarized below:

| Category | Total | Average Per Site |
|---|---|---|
| Total Number of Sites | 20 | NA |
| Total Number of Accidents | 161 | 8.05 |
| Study Period in Years | 4.0 | 4.0 |
| Traffic Volumes Entering | NA | 3616 |
| Accident Rate /MVE | NA | 2.79 |
| No. of Injuries | 60 | 3.0 |
| No. of Fatalities | 0 | 0 |
| Severity in 1000's $ | 870 | 5.40 |
| No. Angle Accidents | 135 | 6.75 |
| No. Rear End Accidents | 4 | 0.20 |
| No. Sideswipe Accidents | 5 | 0.25 |
| No. Pedestrian Accidents | 2 | 0.10 |
| No. Single Vehicle Accidents | 4 | 0.20 |
| No. Left turn Accidents | 4 | 0.20 |
| No. Parked Car Accidents | 6 | 0.30 |
| No. of Other Type Accidents | 1 | 0.05 |

Of all the years in this period, 1988 had the least number of accidents (37), while 1991 had the most with 43. The predominant trend appears to be increasing accidents at the study sites (15% per year). Angle accidents were the most common accident type, which accounts for the relatively high number of injuries. Most of the accidents occurred in clear weather on dry roads. However, a very high percentage 35% of the accidents occurred on snowy or icy streets. Considering the low percentage of time that the streets are in this condition and lower traffic volumes during these conditions, it is apparent that increased winter time maintenance would be warranted.

Night time accidents were not as common as daytime accidents. No fatal accidents occurred within the study sites. The average accident rate per site of 2.79/mve is higher than the typical intersection, as would be expected. There were accident rates as high as 10 accidents/mve at the study sites which is nearly 10 times the urban intersection rate and among the highest calculated within Montana's urban areas.

**Future System Characteristics** - Bozeman has been involved in the process of completing an approved transportation plan which will outline certain transportation improvement projects to be constructed within the next twenty years. Some of the study sites would be affected by this plan in the future. Those sites which will be affected by the plan are discussed in the site analysis sections of this report. Some of the study sites provide short term solutions to problems which would be better served by more capital intensive long range projects or by projects having more far reaching effects than those served by short term improvements. Specific long range recommendations are made in the site specific sections of this report when applicable.

# STUDY METHODOLOGY

The study was segregated into four distinct phases which best achieved the purpose and scope of the traffic study. These phases are outlined as follows:

**Phase 1, Site Selection** - involved copying all of the accident reports on Bozeman city streets for the years 1988 thru of 1991 from Department of Justice files in Helena, Montana. The state reports were sorted and arranged by Avenues and Streets and then cross referenced by intersection. On-system sites for primary highways and major FAU routes, were discarded in the process. The reports were then screened for locations having 5 or more accidents during the reporting period. Cross referenced accidents were confirmed and then entered into a computer program to calculate preliminary hazard index values.

Number of accidents, accident rates and severity indexes were calculated for sixty-six cluster sites. Table 2. is a summary of the screening program. The cluster sites were ranked according to the composite value of three indexes. A recommended list of sites was given to Phillips Forbes, Director of Public Services, City of Bozeman, for his review and approval. The list was modified due to current and local knowledge of projects in progress and projects specifically covered by the TSM element of the new transportation plan. After undesirable sites had been eliminated, the final list of sites was approved.

TABLE 2. CITY OF BOZEMAN - ACCIDENT SITE SCREENING LIST
RANKING BY COMPOSITE ACCIDENT FACTOR

| SITE RAN NO. | INTERSECTION WITH AVENUE or STREET | STREET OR AVENU | ACCIDENTS / YEAR 88 | 89 | 90 | 91 | TOTAL NO. ACC. | NO. ACC. INDEX | APPRO VOLUM | ACC. RATE | ACC. RATE INDE | SVRT INDE | COMPOSITE SCREE INDEX | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | OLIVE | NINTH | 7 | 5 | 7 | 4 | 23 | 69 | 1600 | 9.13 | 115 | 54 | 67.5 | |
| 2 | GRAND | VILLARD | 5 | 4 | 6 | 5 | 20 | 65 | 1500 | 9.53 | 117 | 42 | 63.4 | |
| 3 | OLIVE | SIXTH | 4 | 1 | 5 | 4 | 14 | 76 | 1600 | 5.56 | 66 | 62 | 75.7 | |
| 4 | LAMME | NINTH | 4 | 6 | 5 | 3 | 16 | 62 | 2500 | 5.15 | 63 | 51 | 72.3 | |
| 5 | HARRISON | SEVENTH | 2 | 4 | 4 | 0 | 10 | 67 | 1300 | 5.50 | 67 | 53 | 70.2 | |
| 6 | HAYES | THIRD | 4 | 3 | 3 | 1 | 11 | 69 | 1500 | 5.24 | 84 | 54 | 70.2 | |
| 7 | STORY | FIFTH | 3 | 2 | 2 | 4 | 11 | 69 | 1600 | 4.91 | 81 | 55 | 69.0 | |
| 8 | CURTISS | TRACY | 3 | 4 | 3 | 3 | 13 | 74 | 2200 | 4.22 | 73 | 60 | 68.8 | |
| 9 | BLACK | OLIVE | 3 | 5 | 1 | 4 | 13 | 74 | 2000 | 4.65 | 78 | 42 | 64.9 | |
| 10 | KOCK | ELEVENTH | 12 | 3 | 6 | 6 | 29 | 94 | 6600 | 2.41 | 48 | 59 | 64.5 | FAU |
| 11 | OLIVE | SEVENTH | 2 | 4 | 0 | 2 | 8 | 61 | 1500 | 3.81 | 68 | 59 | 63.2 | |
| 12 | BABCOCK | YELLOWSTONE | 0 | 2 | 2 | 1 | 5 | 50 | 1200 | 2.98 | 57 | 78 | 61.8 | |
| 13 | WESTRIDGE | THIRD | 1 | 5 | 1 | 1 | 6 | 61 | 2000 | 2.66 | 55 | 59 | 57.6 | |
| 14 | KOCK | FIFTEENTH | 2 | 1 | 4 | 1 | 6 | 61 | 1600 | 3.16 | 59 | 52 | 57.4 | |
| 15 | BABCOCK | NINETEENTH | 11 | 6 | 5 | 4 | 26 | 93 | 11000 | 1.62 | 39 | 47 | 56.4 | FAU |
| 16 | LAMME | EIGHTH | 1 | 4 | 3 | 2 | 10 | 67 | 4000 | 1.79 | 36 | 65 | 55.1 | |
| 17 | KOCK | THIRD | 2 | 1 | 2 | 1 | 6 | 54 | 1200 | 3.57 | 66 | 43 | 54.5 | |
| 16 | COLLEGE | EIGHTH | 6 | 12 | 7 | 3 | 26 | 93 | 11600 | 1.73 | 37 | 41 | 54.1 | FAU |
| 19 | BABCOCK | TRACY | 5 | 4 | 6 | 6 | 23 | 69 | 10000 | 1.64 | 35 | 45 | 53.4 | FAU |
| 20 | MENDENHALL | TENTH | 3 | 1 | 3 | 2 | 9 | 64 | 2200 | 2.92 | 56 | 40 | 52.9 | FAU |
| 21 | MENDENHALL | EIGHTH | 4 | 5 | 3 | 0 | 12 | 72 | 4000 | 2.14 | 44 | 47 | 52.7 | FAU |
| 22 | CURTISS | SIXTH | 0 | 1 | 3 | 1 | 5 | 50 | 1100 | 3.25 | 60 | 44 | 52.2 | |
| 23 | GRANT | FIFTH | 2 | 1 | 1 | 2 | 6 | 54 | 1400 | 3.06 | 56 | 43 | 51.6 | |
| 24 | LAMME | FIFTH | 0 | 4 | 2 | 0 | 6 | 54 | 2000 | 2.14 | 44 | 55 | 50.5 | |
| 25 | GRANT | SEVENTH | 2 | 2 | 0 | 1 | 5 | 50 | 1200 | 2.96 | 57 | 33 | 47.0 | |
| 26 | HAYES | FIFTH | 2 | 1 | 1 | 1 | 5 | 50 | 1200 | 2.98 | 57 | 35 | 47.0 | |
| 27 | OLIVE | TRACY | 3 | 2 | 2 | 2 | 9 | 64 | 2800 | 2.30 | 46 | 33 | 46.9 | |
| 26 | COLLEGE | NINETEENTH | 7 | 5 | 4 | 3 | 19 | 64 | 16000 | 0.65 | 20 | 47 | 46.9 | FAU (Low Rate) |
| 29 | WILSON | GRANT | 0 | 4 | 1 | 3 | 6 | 61 | 5200 | 1.10 | 25 | 59 | 48.6 | FAU |
| 30 | TAMMARACK | FIFTH | 1 | 2 | 1 | 1 | 5 | 50 | 2000 | 1.79 | 38 | 52 | 45.9 | FAU |
| 31 | WILSON | OLIVE | 2 | 1 | 2 | 6 | 11 | 69 | 11500 | 0.68 | 17 | 59 | 45.6 | FAU (Low Rate) |
| 32 | BEALL | TWENTYETH | 0 | 2 | 3 | 1 | 6 | 54 | 3600 | 1.19 | 27 | 60 | 45.4 | |
| 33 | BABCOCK | ROUSE | 0 | 6 | 4 | 3 | 13 | 74 | 9000 | 1.03 | 24 | 48 | 45.3 | FAU |
| 34 | BABCOCK | WILLSON | 6 | 3 | 6 | 4 | 19 | 84 | 19000 | 0.71 | 16 | 45 | 45.2 | FAU (low Rate) |
| 35 | DURSTON | ELEVENTH | 4 | 3 | 2 | 6 | 15 | 76 | 16000 | 0.60 | 15 | 53 | 45.0 | FAU (Low Rate) |
| 36 | BEALL | FIFTH | 1 | 1 | 2 | 1 | 5 | 50 | 2200 | 1.62 | 35 | 52 | 44.8 | |
| 37 | LINCOLN | TWELVETH | 1 | 2 | 3 | 1 | 7 | 58 | 3600 | 1.39 | 31 | 48 | 44.0 | |
| 36 | DURSTON | FIFTEENTH | 2 | 1 | 4 | 3 | 10 | 67 | 12000 | 0.60 | 15 | 56 | 43.9 | FAU (Low Rate) |
| 39 | PEACH | BOZEMAN | 2 | 1 | 0 | 2 | 5 | 50 | 5000 | 0.71 | 16 | 69 | 43.7 | FAU (Low Rate) |
| 40 | BOZEMAN | OLIVE | 0 | 2 | 2 | 2 | 6 | 54 | 2500 | 1.72 | 37 | 43 | 43.6 | |
| 41 | LAMME | TENTH | 2 | 3 | 0 | 1 | 6 | 54 | 2500 | 1.72 | 37 | 43 | 43.6 | |
| 42 | LINCOLN | NINETEENTH | 0 | 3 | 0 | 3 | 6 | 54 | 2500 | 1.72 | 37 | 43 | 43.6 | FAU |
| 43 | GARFIELD | SEVENTH | 0 | 5 | 0 | 0 | 5 | 50 | 1500 | 2.38 | 48 | 33 | 43.5 | |
| 44 | WILSON | COLLEGE | 6 | 1 | 2 | 1 | 10 | 67 | 12500 | 0.57 | 14 | 56 | 42.7 | FAU (Low Rate) |
| 45 | COLLEGE | SEVENTH | 3 | 2 | 0 | 2 | 7 | 56 | 3400 | 1.47 | 32 | 41 | 42.5 | FAU |
| 46 | ASPEN | FIFTH | 2 | 0 | 0 | 3 | 5 | 50 | 2200 | 1.62 | 35 | 44 | 42.3 | |
| 47 | BABCOCK | BLACK | 2 | 4 | 4 | 2 | 12 | 72 | 8000 | 0.95 | 22 | 38 | 41.5 | FAU |
| 48 | KOCK | NINETEENTH | 2 | 0 | 1 | 4 | 7 | 56 | 6500 | 0.59 | 15 | 59 | 41.4 | FAU (Low Rate) |
| 49 | GARFIELD | WILSON | 2 | 4 | 3 | 0 | 9 | 64 | 8000 | 1.07 | 25 | 40 | 40.6 | FAU |
| 50 | BABCOCK | FIFTH | 2 | 0 | 2 | 4 | 6 | 61 | 6500 | 0.67 | 17 | 52 | 40.7 | FAU (Low Rate) |
| 51 | VILLARD | FIFTH | 1 | 2 | 4 | 3 | 10 | 67 | 8000 | 0.89 | 21 | 39 | 40.0 | Low Acc Rate |
| 52 | BABCOCK | SEVENTH | 1 | 1 | 2 | 2 | 6 | 54 | 8000 | 0.71 | 16 | 51 | 38.6 | FAU (Low Rate) |
| 53 | CLEVELAND | ELEVENTH | 0 | 2 | 2 | 1 | 5 | 50 | 12000 | 0.30 | 6 | 64 | 36.3 | FAU (Low Rate) |
| 54 | COLLEGE | NINTH | 1 | 2 | 3 | 2 | 6 | 61 | 5000 | 1.14 | 26 | 33 | 38.2 | FAU |
| 55 | COLLEGE | FIFTEENTH | 1 | 1 | 3 | 2 | 7 | 56 | 8000 | 0.63 | 16 | 48 | 38.0 | FAU (Low Rate) |
| 56 | ARTHUR | THIRD | 2 | 2 | 1 | 1 | 6 | 54 | 8500 | 0.66 | 16 | 49 | 37.9 | Low Rate |
| 57 | TRACY | BEALL | 1 | 0 | 2 | 2 | 5 | 50 | 2500 | 1.43 | 32 | 35 | 37.2 | FAU |
| 58 | BABCOCK | ELEVENTH | 3 | 1 | 1 | 3 | 6 | 61 | 13500 | 0.42 | 11 | 48 | 36.7 | FAU (Low Rate) |
| 59 | GARFIELD | NINETEENTH | 1 | 3 | 2 | 2 | 6 | 61 | 9000 | 0.64 | 16 | 41 | 36.7 | FAU (Low Rate) |
| 60 | LINCOLN | ELEVENTH | 2 | 4 | 1 | 1 | 6 | 61 | 14000 | 0.41 | 11 | 48 | 36.6 | Low Rate |
| 61 | BABCOCK | GRAND | 0 | 2 | 3 | 0 | 5 | 50 | 7000 | 0.51 | 13 | 44 | 33.7 | FAU (Low Rate) |
| 62 | TRACY | VILLARD | 1 | 1 | 3 | 0 | 5 | 50 | 8000 | 0.45 | 12 | 44 | 33.2 | FAU (Low Rate) |
| 63 | ALDERSON | ELEVENTH | 1 | 3 | 1 | 2 | 7 | 58 | 6400 | 0.60 | 15 | 33 | 32.9 | FAU (Low Rate) |
| 64 | BABCOCK | BOZEMAN | 1 | 0 | 0 | 5 | 6 | 54 | 8000 | 0.48 | 12 | 33 | 30.9 | Low Rate |
| 65 | BEALL | NINETEENTH | 1 | 1 | 2 | 1 | 5 | 50 | 7000 | 0.51 | 13 | 33 | 30.0 | FAU (Low Rate) |
| 66 | BABCOCK | EIGHTH | 2 | 0 | 2 | 1 | 5 | 50 | 13800 | 0.26 | 7 | 33 | 27.7 | FAU (Low Rate) |
| | | TOTALS = | 142 | 155 | 143 | 126 | 568 | | | | | | | |
| | | AVE. YEAR = | 2.7 | 2.9 | 2.7 | 2.4 | 10.7 | 65.2 | 5230.2 | 2.5 | 44.9 | 49.8 | 52.2 | |

Composite Index: Number Accidents = 28%, Accident Rate= 39%, Severity = 33%

**Phase 2, Data Collection** - included preliminary organization of the project including scheduling, site location, form processing, field data collection and reduction of data. Accident data was obtained from reports provided by the Department of Justice. Traffic counts were taken at each location. The existing average daily traffic was determined by applying factors for hourly, daily and monthly variations. Other data collected in the field, included measurement of road widths and geometrics, and inventory of traffic control devices, turning movement counts and subjective observation of traffic operations. Gaston Engineering of Bozeman performed the field topo surveys, sign inventories and base sheet drafting.

**Phase 3, Analysis of Data** - included the determination of hazard indexes for each location by using the Federal Highway Administration Report *No. FHWA-RD-77-83 "Identification of Hazardous Locations".* Computations involved with accidents, volumes, capacities, indicator values and other aspects of hazard indexes were performed on a microcomputer using original templates for Ouattro Pro Ver. 4.0, developed by Marvin & Associates. Regression equations were developed to mathematically simulate hazard index curves contained in the FHA report. From these computations a preliminary hazard ranking list was prepared.

**Phase 4, Evaluation of Corrective Measures** - included the determination of improvements that would reduce or eliminate certain types of accidents or accidents in general at the study locations. Preliminary designs of those improvements included signing, geometric changes, and some minor reconstruction. The improvements were recommended on a short term basis. In most cases, the nature of the sites were such that long term improvements would not provide additional benefits-beyond those expected through implementation of short term improvements.

Cost effectiveness calculations of the improvements at each location were determined by preparing preliminary cost estimates and computing economic benefits to arrive at a benefit/cost ratio. The method used to determine benefit/cost ratios is identical to that used by the Montana Department of Transportation Project Planning Section. All values used in the formulation were supplied by Hank Butzlaff, supervisor of that section. The composite hazard index ranking and benefit/cost ratio, then determined the final priority listing.

# HAZARD INDEX ANALYSIS RESULTS

Seven hazard indexes were used as the preliminary basis of ranking hazardous sites. The following are brief descriptions of each index including data format, data collection, indicator scaling and site ranking with respect to each index.

1. **Number of Accidents** - This indicator provides a historical background of accidents at the investigation site. In the case of Bozeman, a four year period was used, which included 1988 thru 1991. The accident reports were photo copied in Helena and provided to the consultant. The data represents all reports filed within the city limits of Bozeman.

Figure 6. is a curve extracted from the FHWA report which was used to determine the indicator value. The data base is number of accidents per year. This indicator, as with all of the seven indicators used in the report, is scaled between 0 and 100. An average of two accidents per year in a three year period indicates a hazardous location (indicator value of 33). An average of ten accidents per year is used to designate a very hazardous location (indicator value of 67). In the case of this study, the total number of accidents per site criteria was used to extract the index value rather than the annual rate. This higher value is therefore more consistent with the level of the other index values. Using an annual rate would have scaled down the importance of this indicator relative to other index values. Table 3. is the computer generated ranking of all sites based on this indicator. It can be seen that none of the sites exceeded the maximum value of 100 and the average value was in the same range as other hazard index values.

2. **Accident Rate Indicator** - This indicator somewhat compensates for any incomplete information provided by the number of accident indicator in that an exposure value is provided by the relationship between accidents and the total volume of vehicles using the facility. This indicator is expressed as the number of accidents per million entering vehicles. In the case of an intersection, "million entering vehicles" is the sum of the daily average approach volumes on all legs of the intersection, multiplied by the number of days in the analysis period.

## TABLE 3. SITE RANKING BY NUMBER OF ACCIDENTS

| RANK NO. | AVENUE | STREET | ACCIDENTS / YEAR 88 | 89 | 90 | 91 | TOTAL NO. ACC. | NO. ACC. INDEX |
|---|---|---|---|---|---|---|---|---|
| 1 | CURTISS | TRACY | 3 | 4 | 3 | 4 | 14 | 76 |
| 2 | OLIVE | BLACK | 3 | 5 | 2 | 4 | 14 | 76 |
| 3 | HAYES | THIRD | 4 | 2 | 3 | 2 | 11 | 69 |
| 4 | OLIVE | TRACY | 4 | 1 | 2 | 4 | 11 | 69 |
| 5 | STORY | FIFTH | 3 | 2 | 2 | 3 | 10 | 67 |
| 6 | VILLARD | FIFTH | 1 | 2 | 3 | 4 | 10 | 67 |
| 7 | GARFIELD | WILLSON | 2 | 4 | 3 | 0 | 9 | 64 |
| 8 | MENDENHALL | TENTH | 3 | 1 | 3 | 2 | 9 | 64 |
| 9 | LAMME | FIFTH | 0 | 4 | 2 | 2 | 8 | 61 |
| 10 | OLIVE | SEVENTH | 2 | 4 | 0 | 2 | 8 | 61 |
| 11 | TAMARACK | FIFTH | 1 | 2 | 1 | 3 | 7 | 58 |
| 12 | ARTHUR | THIRD | 2 | 2 | 1 | 1 | 6 | 54 |
| 13 | BABCOCK | YELLOWSTONE | 0 | 2 | 2 | 2 | 6 | 54 |
| 14 | KOCH | THIRD | 2 | 1 | 2 | 1 | 6 | 54 |
| 15 | OLIVE | BOZEMAN | 0 | 2 | 2 | 2 | 6 | 54 |
| 16 | VILLARD | TRACY | 1 | 1 | 3 | 1 | 6 | 54 |
| 17 | BEALL | TRACY | 1 | 0 | 2 | 2 | 5 | 50 |
| 18 | BEALL | FIFTH | 1 | 1 | 2 | 1 | 5 | 50 |
| 19 | HAYES | FIFTH | 2 | 1 | 1 | 1 | 5 | 50 |
| 20 | PEACH | BOZEMAN | 2 | 1 | 0 | 2 | 5 | 50 |
| | | TOTALS = | 37 | 42 | 39 | 43 | 161 | |
| | | AVERAGES = | 1.9 | 2.1 | 2.0 | 2.2 | 8.1 | 60.2 |

The accident rate indicator is a very important part of the hazard index ranking method and data collection is possible when a continued program of traffic counting has been performed. Spot counts adjusted by yearly volume increases, seasonal variations, daily variations and hourly variations were necessary at most of the sites to develop an average daily traffic figure applied to the analysis period.

Figure 7 represents the graphic plot of accident rate versus indicator value. As before, the indicator value ranges between 0 and 100. Table 4 is the computer generated ranking of sites based on this indicator. It can be seen that the intersections included in this study produced a wide range of accident rates commensurate with large differences in traffic volumes. The average rate index was 45.

**3. Accident Severity Indicator** - Although there are many factors involved in the severity of accidents, statistical studies over a significant number of years have given fairly reliable dollar values in terms of economic loss for each type of accident. The accident severity indicator correlates a probable cause and effect relationship which aids in the determination of the level of accident reduction measures required. Severity values can also be used as a determinant of benefits resulting from various improvements. The data base for accident severity is average relative severity in thousands of dollars. Data collection necessary for the use of the severity index is made possible by the accident report form. Dollar values for severity were provided by Hank Butzlaff of the Montana Department of Transportation. They are: Fatal Accident = $500,000, Injury Accident = $11,000 and Property Damage Accident = $2,000. Recently, the method of calculating fatal and injury costs was changed by MDoT to include total number of persons injured or killed rather than just an injury or fatal accident as a single incident. In the case of this study, some single accidents produced multiple injuries which increased the relative severity of those sites significantly.

The FHWA report presents the relative severity index values for each type of accident. Once the type of accident has been established, Figure 8 enables the user to assess the indicator value. Figure 8 is a graphic plot of the average severity in thousands of dollars versus the indicator value which is based on a scale of 0 to 100. Table 5 is the computer generated ranking of sites based on this indicator.

## TABLE 4. SITE RANKING BY ACCIDENT RATE

| RANK NO. | STREET/AVE | STREET/AVE | NO. ACC. 4.00 YEARS | 1991 ADT | ADT PERIOD AVE. | AC. RATE (MVE) | ACC RATE IND VALUE |
|---|---|---|---|---|---|---|---|
| 1 | STORY | FIFTH | 10 | 700 | 672 | 10.19 | 100 |
| 2 | HAYES | THIRD | 11 | 800 | 768 | 9.81 | 100 |
| 3 | KOCH | THIRD | 6 | 850 | 816 | 5.04 | 82 |
| 4 | CURTISS | TRACY | 14 | 2450 | 2352 | 4.08 | 71 |
| 5 | ARTHUR | THIRD | 6 | 1300 | 1248 | 3.29 | 61 |
| 6 | VILLARD | FIFTH | 10 | 2250 | 2160 | 3.17 | 59 |
| 7 | OLIVE | SEVENTH | 8 | 2025 | 1944 | 2.82 | 54 |
| 8 | HAYES | FIFTH | 5 | 1400 | 1344 | 2.55 | 50 |
| 9 | LAMME | FIFTH | 8 | 2500 | 2400 | 2.28 | 46 |
| 10 | VILLARD | TRACY | 6 | 2150 | 2064 | 1.99 | 41 |
| 11 | OLIVE | BLACK | 14 | 5550 | 5328 | 1.80 | 38 |
| 12 | BABCOCK | YELLOWSTONE | 6 | 2550 | 2448 | 1.68 | 36 |
| 13 | BEALL | FIFTH | 5 | 2900 | 2784 | 1.23 | 28 |
| 14 | BEALL | TRACY | 5 | 3100 | 2976 | 1.15 | 26 |
| 15 | OLIVE | TRACY | 11 | 7000 | 6720 | 1.12 | 26 |
| 16 | MENDENHALL | TENTH | 9 | 6550 | 6288 | 0.98 | 23 |
| 17 | OLIVE | BOZEMAN | 6 | 5100 | 4896 | 0.84 | 20 |
| 18 | PEACH | BOZEMAN | 5 | 5150 | 4944 | 0.69 | 17 |
| 19 | GARFIELD | WILLSON | 9 | 11200 | 10752 | 0.57 | 15 |
| 20 | TAMARACK | FIFTH | 7 | 9350 | 8976 | 0.53 | 14 |
| | | AVERAGE VALUE | 8 | 3,744 | 3,594 | 3 | 45 |

## TABLE 5. SITE RANKING BY ACCIDENT SEVERITY

| RANK NO. | AVENUES | STREETS | SUM OF SEVERITY VALUES | TOTAL NO. ACC. | AVERAGE SEVERITY INDEX | INDICATOR VALUE |
|---|---|---|---|---|---|---|
| 1 | BABCOCK | YELLOWSTONE | $92,000 | 6 | $15,333 | 76 |
| 2 | PEACH | BOZEMAN | $59,000 | 5 | $11,800 | 69 |
| 3 | CURTISS | TRACY | $126,000 | 14 | $9,000 | 62 |
| 4 | OLIVE | SEVENTH | $63,000 | 8 | $7,875 | 59 |
| 5 | HAYES | THIRD | $78,000 | 11 | $7,091 | 56 |
| 6 | STORY | FIFTH | $60,000 | 10 | $6,000 | 53 |
| 7 | TAMARACK | FIFTH | $41,000 | 7 | $5,857 | 52 |
| 8 | BEALL | FIFTH | $28,000 | 5 | $5,600 | 51 |
| 9 | LAMME | FIFTH | $43,000 | 8 | $5,375 | 50 |
| 10 | ARTHUR | THIRD | $30,000 | 6 | $5,000 | 49 |
| 11 | OLIVE | BLACK | $55,000 | 14 | $3,929 | 45 |
| 12 | BEALL | TRACY | $19,000 | 5 | $3,800 | 44 |
| 13 | OLIVE | TRACY | $40,000 | 11 | $3,636 | 43 |
| 14 | KOCH | THIRD | $21,000 | 6 | $3,500 | 43 |
| 15 | OLIVE | BOZEMAN | $21,000 | 6 | $3,500 | 43 |
| 16 | VILLARD | TRACY | $21,000 | 6 | $3,500 | 43 |
| 17 | GARFIELD | WILLSON | $27,000 | 9 | $3,000 | 40 |
| 18 | MENDENHALL | TENTH | $27,000 | 9 | $3,000 | 40 |
| 19 | VILLARD | FIFTH | $29,000 | 10 | $2,900 | 40 |
| 20 | HAYES | FIFTH | $10,000 | 5 | $2,000 | 34 |
| | | TOTAL SEVERITY $ = | $890,000 | | | |
| | | TOTAL NO. ACC. = | | 161 | | |
| | | AVE. SEVERITY / ACC. = | | | $5,528 | |
| | | AVE. IND. VAL / SITE = | | | | 50 |

4. **Volume to Capacity Ratio Indicator** - This indicator not only reflects exposure rates but also incorporates existing street geometry, access and conditions such as traffic type, turning directions, volume mix and number of lanes. Computation of the volume capacity indicator is expressed as follows:

*V/C = ADT/24 HOUR CAPACITY*

Modifications to the basic V/C formula were felt necessary because of the predominance of intersections within this study and the vast changes that have occurred in capacity theory since the time when the FHWA report was published. Use of the original formula would have diluted the relative importance of this indicator if calculated in this manner. Therefore, volume/capacity calculation using the 1985 Highway Capacity Manual procedures were used and expressed as a peak hour V/C. Calculations of peak hour V/C in this manner also gives an indication of intersection efficiency and aids in the development of potential improvements.

Data required for the volume capacity ratio involved field measurements of existing geometrics, turning counts and volume mix. The capacity of each intersection is computed through methodology presented in the 1985 *Highway Capacity Manual* using FHWA computer software. Although this indicator is cumbersome to use by inexperienced personnel, its inclusion is considered necessary and correlates well in hazardous index ranking.

Figure 9. presents a graphic plot of the volume capacity ratio versus the indicator value which is also scaled between 0 and 100. Table 6. is the computer generated ranking of the sites based on this indicator. The average value for this indicator was 36 while values ranged between 6 and 100.

## TABLE 6. SITE RANKING BY VOLUME/CAPACITY RATIOS

| RANK NO. | STREET/AVE | STREET/AVE | PEAK HOUR CAPACI | PEAK HOUR FLOW | * V/C RATIO | V/C INDICATOR VALUE |
|---|---|---|---|---|---|---|
| 1 | TAMARACK | FIFTH | 220 | 207 | 0.94 | 100 |
| 2 | GARFIELD | WILLSON | 58 | 48 | 0.83 | 100 |
| 3 | OLIVE | TRACY | 688 | 290 | 0.42 | 68 |
| 4 | OLIVE | BLACK | 805 | 259 | 0.32 | 57 |
| 5 | OLIVE | SEVENTH | 971 | 91 | 0.21 | 42 |
| 6 | MENDENHALL | TENTH | 331 | 68 | 0.21 | 41 |
| 7 | PEACH | BOZEMAN | 330 | 66 | 0.20 | 41 |
| 8 | OLIVE | BOZEMAN | 791 | 141 | 0.18 | 38 |
| 9 | BEALL | FIFTH | 801 | 128 | 0.16 | 35 |
| 10 | BEALL | TRACY | 721 | 104 | 0.14 | 32 |
| 11 | LAMME | FIFTH | 893 | 101 | 0.11 | 27 |
| 12 | VILLARD | FIFTH | 868 | 86 | 0.10 | 25 |
| 13 | BABCOCK | YELLOWSTONE | 945 | 88 | 0.09 | 24 |
| 14 | VILLARD | TRACY | 802 | 72 | 0.09 | 23 |
| 15 | CURTISS | TRACY | 881 | 59 | 0.07 | 19 |
| 16 | ARTHUR | THIRD | 943 | 42 | 0.04 | 14 |
| 17 | HAYES | FIFTH | 955 | 33 | 0.03 | 12 |
| 18 | STORY | FIFTH | 946 | 25 | 0.03 | 10 |
| 19 | KOCH | THIRD | 987 | 25 | 0.03 | 9 |
| 20 | HAYES | THIRD | 997 | 14 | 0.01 | 6 |
| | | AVERAGE VALUES | 747 | 97 | 0 | 36 |

* V/C Refers to capacity of the minor street in the case of uncontrolled or stop/yeild controlled intersections.

** V/C Refers to average v/c for all legs of signalized intersection or a four way stop intersection.

**5. Sight Distance Indicator** - This indicator is of significant value in both rural and urban locations, especially at intersections. Even though the weighting factor in the hazard index computation is low, it is still considered valuable in determining cause and effect relationships and other deficiencies at the accident cluster sites.

The data format for using the sight distance indicator is the ratio of actual sight distance to desirable sight distance. The FHWA report presents the minimum stopping sight distance on wet pavement for the various design speeds. Actual stopping sight distance is the distance from the drivers position to the point where a stop may be required to avoid a hazardous maneuver or direct collision. Required sight distances vary according to the type of control encountered. At uncontrolled intersections specific AASHTO guidelines for this situation are used. At stop controlled and signalized intersections two different requirements are applied: 1. stopping sight distance to the control device & 2. intersection sight distance required to cross the intersection. The various required sight distances and measured values are computed and combined according to the study method's formulation to determine the indicator value.

The data format for this indicator is the sight distance ratio of actual over desirable. Collection of the sight distance data requires field measurements of sight distance and determination of average travel speeds. Figure 10. presents a graphic plot of the sight distance ratio versus the indicator value which ranges from 0 to 100. Table 7. is the computer generated ranking of sites based on this indicator. A total of 2 sites had indicator values of 100 and they ranged down to 30. Considering all of the possible restrictions present in an urban environment, the higher values should not be unexpected.

## TABLE 7. SITE RANKING BY SIGHT DISTANCE

| RANK NO. | INTERSECTION LOCATION | | APP1 SD | REQ SD | RATIO | APP2 SD | REQ SD | RATIO | APP3 SD | REQ SD | RATIO | APP4 SD | REQ SD | RATIO | *WT. IND VAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MENDENHALL | TENTH | 85 | 200 | 0.43 | 150 | 300 | 0.50 | 80 | 200 | 0.40 | 120 | 300 | 0.40 | 100 |
| 2 | BEALL | FIFTH | 180 | 200 | 0.90 | 80 | 200 | 0.40 | 150 | 300 | 0.50 | 150 | 300 | 0.50 | 100 |
| 3 | STORY | FIFTH | 70 | 110 | 0.64 | 60 | 110 | 0.55 | 60 | 110 | 0.55 | 70 | 110 | 0.64 | 97 |
| 4 | GARFIELD | WILLSON | 120 | 200 | 0.60 | 120 | 200 | 0.60 | 160 | 300 | 0.53 | 180 | 300 | 0.60 | 96 |
| 5 | TAMARACK | FIFTH | 400 | 200 | 2.00 | 130 | 200 | 0.65 | 160 | 300 | 0.53 | 350 | 300 | 1.17 | 92 |
| 6 | LAMME | FIFTH | 70 | 110 | 0.64 | 60 | 110 | 0.55 | 70 | 110 | 0.64 | 75 | 110 | 0.68 | 90 |
| 7 | CURTISS | TRACY | 60 | 110 | 0.55 | 70 | 110 | 0.64 | 85 | 110 | 0.77 | 85 | 110 | 0.77 | 90 |
| 8 | ARTHUR | THIRD | 60 | 110 | 0.55 | 70 | 110 | 0.64 | 120 | 110 | 1.09 | 100 | 110 | 0.91 | 90 |
| 9 | OLIVE | TRACY | 80 | 110 | 0.73 | 75 | 110 | 0.68 | 60 | 110 | 0.55 | 90 | 110 | 0.82 | 87 |
| 10 | PEACH | BOZEMAN | 200 | 200 | 1.00 | 200 | 200 | 1.00 | 160 | 300 | 0.53 | 220 | 300 | 0.73 | 86 |
| 11 | HAYES | THIRD | 80 | 110 | 0.73 | 60 | 110 | 0.55 | 95 | 110 | 0.86 | 90 | 110 | 0.82 | 83 |
| 12 | VILLARD | TRACY | 85 | 110 | 0.77 | 60 | 110 | 0.55 | 85 | 110 | 0.77 | 85 | 110 | 0.77 | 81 |
| 13 | KOCH | THIRD | 70 | 110 | 0.64 | 75 | 110 | 0.68 | 70 | 110 | 0.64 | 90 | 110 | 0.82 | 78 |
| 14 | HAYES | FIFTH | 100 | 110 | 0.91 | 60 | 110 | 0.55 | 95 | 110 | 0.86 | 130 | 110 | 1.18 | 75 |
| 15 | VILLARD | FIFTH | 80 | 110 | 0.73 | 70 | 110 | 0.64 | 100 | 110 | 0.91 | 85 | 110 | 0.77 | 72 |
| 16 | OLIVE | BOZEMAN | 80 | 110 | 0.73 | 80 | 110 | 0.73 | 70 | 110 | 0.64 | 100 | 110 | 0.91 | 72 |
| 17 | OLIVE | BLACK | 85 | 110 | 0.77 | 80 | 110 | 0.73 | 80 | 110 | 0.73 | 70 | 110 | 0.64 | 72 |
| 18 | OLIVE | SEVENTH | 85 | 110 | 0.77 | 80 | 110 | 0.73 | 75 | 110 | 0.68 | 100 | 110 | 0.91 | 68 |
| 19 | BEALL | TRACY | 110 | 110 | 1.00 | 75 | 110 | 0.68 | 75 | 110 | 0.68 | 75 | 110 | 0.68 | 60 |
| 20 | BABCOCK | YELLOWSTON | 110 | 110 | 1.00 | 140 | 110 | 1.27 | 130 | 110 | 1.18 | 180 | 110 | 1.64 | 30 |
| | | | | | | | | | | | | | | AVERAGE INDICATOR VALUE | 81.0 |

* WEIGHTED INDICATOR VALUE IS CALCULATED BY THE FORMULA (2xHIGHVAL + 2ndHIGHVAL)/3

APP# SD's = MEASURED SIGHT DISTANCE ON DIRECTIONAL APPROACHES FOR VARIOUS CONDITIONS OF CONTROL

REQ SD = REQUIRED SIGHT DISTANCE ACCORDING TO AASHO

6. **Driver Expectancy Indicator** - This indicator relates human behavior factors to existing road conditions. The value of this indicator is realized in the fact that the roadway geometrics and roadside culture are evaluated on a human judgement basis.

The data format for the driver expectancy index is the problem rating scale. Being a subjective indicator, the degree of expectancy is rated on a scale from 1 to 6, and the expectancy rating varies linearly with the indicator value as shown in Figure 11. The expectancy rating form can be found in the FHWA report for further reference. Table 8. is the computer generated ranking of sites based on this indicator.

**TABLE 8. SITE RANKING BY DRIVER EXPECTANCY**

| RANK NO. | AVENUE | STREET | NB RATE | SB RATE | EB RATE | WB RATE | WGTD. RATE | IND VAL |
|---|---|---|---|---|---|---|---|---|
| 1 | OLIVE | TRACY | 6 | 6 | 6 | 6 | 6.0 | 100 |
| 2 | OLIVE | BLACK | 6 | 6 | 4 | 6 | 5.5 | 92 |
| 3 | ARTHUR | THIRD | 3 | 4 | 6 | 6 | 4.8 | 79 |
| 4 | TAMARACK | FIFTH | 5 | 5 | 5 | 3 | 4.5 | 75 |
| 5 | OLIVE | SEVENTH | 3 | 5 | 4 | 6 | 4.5 | 75 |
| 6 | OLIVE | BOZEMAN | 5 | 5 | 4 | 4 | 4.5 | 75 |
| 7 | CURTISS | TRACY | 5 | 6 | 3 | 3 | 4.3 | 71 |
| 8 | BABCOCK | YELLOWSTONE | 4 | 5 | 3 | 5 | 4.3 | 71 |
| 9 | VILLARD | TRACY | 4 | 4 | 4 | 4 | 4.0 | 67 |
| 10 | GARFIELD | WILLSON | 4 | 5 | 4 | 3 | 4.0 | 67 |
| 11 | MENDENHALL | TENTH | 4 | 4 | 4 |  | 4.0 | 67 |
| 12 | HAYES | THIRD | 5 | 3 | 5 | 3 | 4.0 | 67 |
| 13 | STORY | FIFTH | 3 | 4 | 3 | 5 | 3.8 | 63 |
| 14 | VILLARD | FIFTH | 3 | 3 | 5 | 4 | 3.8 | 63 |
| 15 | KOCH | THIRD | 3 | 4 | 4 | 4 | 3.8 | 63 |
| 16 | LAMME | FIFTH | 3 | 3 | 5 | 4 | 3.8 | 63 |
| 17 | BEALL | TRACY | 4 | 4 | 3 | 3 | 3.5 | 58 |
| 18 | HAYES | FIFTH | 4 | 3 | 3 | 4 | 3.5 | 58 |
| 19 | PEACH | BOZEMAN | 4 | 3 | 4 | 3 | 3.5 | 58 |
| 20 | BEALL | FIFTH | 3 | 3 | 3 | 3 | 3.0 | 50 |
|  |  |  |  |  | AVERAGE INDICATOR VALUE = |  |  | 69.0 |

7. **Information System Deficiencies Indicator** - This indicator also provides a value or subjective judgement on the sufficiency of traffic control devices which transfer necessary information to the operator.

The data format for the information system deficiencies indicator is similar to that of the driver expectancy indicator in that a value form is used to provide a rating between 1 and 6. The rating for this indicator is also plotted linearly between the indicator range values of 0 and 100 and is shown on Figure 12. The value rating form is for the information system deficiencies indicator. It is also presented in the FHWA report for further reference. Table 9. is the computer generated ranking of sites based on this indicator.

TABLE 9. SITE RANKING BY INFORMATION DEFICIENCY

| RANK NO. | STREET/AVE | STREET/AVE | NB RATE | SB RATE | EB RATE | WB RATE | WGTD. RATE | IND VAL |
|---|---|---|---|---|---|---|---|---|
| 1 | OLIVE | TRACY | 6 | 6 | 5 | 5 | 5.5 | 92 |
| 2 | MENDENHALL | TENTH | 5 | 5 | | 6 | 5.3 | 89 |
| 3 | LAMME | FIFTH | 5 | 5 | 5 | 5 | 5.0 | 83 |
| 4 | OLIVE | BLACK | 5 | 5 | 4 | 5 | 4.8 | 79 |
| 5 | TAMARACK | FIFTH | 5 | 4 | 5 | 5 | 4.8 | 79 |
| 6 | OLIVE | BOZEMAN | 5 | 5 | 4 | 4 | 4.5 | 75 |
| 7 | CURTISS | TRACY | 4 | 4 | 5 | 5 | 4.5 | 75 |
| 8 | BEALL | TRACY | 4 | 4 | 5 | 5 | 4.5 | 75 |
| 9 | VILLARD | TRACY | 4 | 4 | 5 | 5 | 4.5 | 75 |
| 10 | VILLARD | FIFTH | 5 | 5 | 4 | 4 | 4.5 | 75 |
| 11 | BEALL | FIFTH | 5 | 5 | 4 | 4 | 4.5 | 75 |
| 12 | STORY | FIFTH | 4 | 4 | 4 | 4 | 4.0 | 67 |
| 13 | PEACH | BOZEMAN | 4 | 4 | 4 | 4 | 4.0 | 67 |
| 14 | GARFIELD | WILLSON | 4 | 5 | 4 | 3 | 4.0 | 67 |
| 15 | HAYES | THIRD | 4 | 4 | 4 | 4 | 4.0 | 67 |
| 16 | OLIVE | SEVENTH | 5 | 4 | 3 | 4 | 4.0 | 67 |
| 17 | ARTHUR | THIRD | 4 | 4 | 4 | 4 | 4.0 | 67 |
| 18 | KOCH | THIRD | 4 | 4 | 3 | 3 | 3.5 | 58 |
| 19 | BABCOCK | YELLOWSTONE | 3 | 3 | 3 | 3 | 3.0 | 50 |
| 20 | HAYES | FIFTH | 3 | 3 | 3 | 3 | 3.0 | 50 |
| | | | | AVERAGE INDICATOR VALUE = | | | | 71.5 |

## HAZARD RANKING

Once all of the data had been collected and the indicator values computed, indicator values and necessary data were transferred to the hazard index computation matrix. Each indicator was weighted in accordance with the FHWA report. The weighting factors are fractional portions of unity. When all nine indicators established in FHWA report are used, the sum of weights is equal to one. In the case of Bozeman, two indicators were omitted, the Traffic Conflict Indicator and the Erratic Maneuvers Indicator. Their exclusion from the study was not felt to be any detriment in the ranking of hazardous sites. The use of seven indicators provided an 88.6% confidence in strength of evaluation.

Based on the hazard analysis for each site, a matrix of indicator values and final hazard index ratings was constructed on a Quattro Pro template and a hazard index ranking was completed. Table 10., on the following page, lists this ranking by site number, location, indicator values and hazard index. Also shown is statistical information for the indicator values and hazard index.

## TABLE 10. SITE RANKING BY HAZARD INDEX - SUMMARY OF INDICATOR VALUES

| RANK NO. | | | # OF ACC. | | ACC. RATE | | SEVERITY | | V/C RATIO | | SIGHT DIST | | EXPECT. | | INFO DEF. | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | IND VAL | PART H.I. | IND VAL | PART H.I. | IND VAL | PART H.I. | IND VAL | PART H.I. | IND VAL | PART H.I. | IND VAL | PART H.I. | IND VAL | PART H.I. | HAZAR INDEX |
| | | | | Wgt. 16.4% | | Wgt. 22.5% | | Wgt. 19.1% | | Wgt. 8.2% | | Wgt. 7.4% | | Wgt. 14.9% | | Wgt. 11.5% | Wgt 100% |
| 1 | HAYES | THIRD | 69 | 11.2 | 100 | 22.4 | 56 | 10.6 | 6 | 0.5 | 83 | 6.1 | 67 | 9.9 | 67 | 7.7 | 68.5 |
| 2 | STORY | FIFTH | 67 | 10.9 | 100 | 22.4 | 53 | 10.1 | 10 | 0.8 | 97 | 7.2 | 63 | 9.3 | 67 | 7.7 | 68.4 |
| 3 | CURTISS | TRACY | 76 | 12.4 | 71 | 15.9 | 62 | 11.8 | 19 | 1.6 | 90 | 6.7 | 71 | 10.5 | 75 | 8.6 | 67.4 |
| 4 | OLIVE | TRACY | 69 | 11.2 | 26 | 5.8 | 43 | 8.2 | 68 | 5.6 | 87 | 6.4 | 100 | 14.8 | 92 | 10.6 | 62.6 |
| 5 | OLIVE | BLACK | 76 | 12.4 | 38 | 8.5 | 45 | 8.6 | 57 | 4.7 | 72 | 5.3 | 92 | 13.6 | 79 | 9.1 | 62.2 |
| 6 | OLIVE | SEVENTH | 61 | 9.9 | 54 | 12.1 | 59 | 11.2 | 42 | 3.4 | 68 | 5.0 | 75 | 11.1 | 67 | 7.7 | 60.5 |
| 7 | ARTHUR | THIRD | 54 | 8.8 | 61 | 13.7 | 49 | 9.3 | 14 | 1.1 | 90 | 6.7 | 79 | 11.7 | 67 | 7.7 | 59.0 |
| 8 | KOCH | THIRD | 54 | 8.8 | 82 | 18.4 | 43 | 8.2 | 9 | 0.7 | 78 | 5.8 | 63 | 9.3 | 58 | 6.7 | 57.8 |
| 9 | TAMARACK | FIFTH | 58 | 9.5 | 14 | 3.1 | 52 | 9.9 | 100 | 8.2 | 92 | 6.8 | 75 | 11.1 | 79 | 9.1 | 57.7 |
| 10 | LAMME | FIFTH | 61 | 9.9 | 46 | 10.3 | 50 | 9.5 | 27 | 2.2 | 90 | 6.7 | 63 | 9.3 | 83 | 9.5 | 57.5 |
| 11 | VILLARD | FIFTH | 67 | 10.9 | 59 | 13.2 | 40 | 7.6 | 25 | 2.1 | 72 | 5.3 | 63 | 9.3 | 75 | 8.6 | 57.1 |
| 12 | GARFIELD | WILLSON | 64 | 10.4 | 15 | 3.4 | 40 | 7.6 | 100 | 8.2 | 96 | 7.1 | 67 | 9.9 | 67 | 7.7 | 54.3 |
| 13 | MENDENHALL | TENTH | 64 | 10.4 | 23 | 5.2 | 40 | 7.6 | 41 | 3.4 | 100 | 7.4 | 67 | 9.9 | 89 | 10.2 | 54.1 |
| 14 | VILLARD | TRACY | 54 | 8.8 | 41 | 9.2 | 43 | 8.2 | 23 | 1.9 | 81 | 6.0 | 67 | 9.9 | 75 | 8.6 | 52.6 |
| 15 | BABCOCK | YELLOWSTONE | 54 | 8.8 | 36 | 8.1 | 76 | 14.4 | 24 | 2.0 | 30 | 2.2 | 71 | 10.5 | 50 | 5.8 | 51.8 |
| 16 | PEACH | BOZEMAN | 50 | 8.2 | 17 | 3.8 | 69 | 13.1 | 41 | 3.4 | 86 | 6.4 | 58 | 8.6 | 67 | 7.7 | 51.1 |
| 17 | BEALL | FIFTH | 50 | 8.2 | 28 | 6.3 | 51 | 9.7 | 35 | 2.9 | 100 | 7.4 | 50 | 7.4 | 75 | 8.6 | 50.4 |
| 18 | OLIVE | BOZEMAN | 54 | 8.8 | 20 | 4.5 | 43 | 8.2 | 38 | 3.1 | 72 | 5.3 | 75 | 11.1 | 75 | 8.6 | 49.6 |
| 19 | HAYES | FIFTH | 50 | 8.2 | 50 | 11.2 | 34 | 6.5 | 12 | 1.0 | 75 | 5.6 | 58 | 8.6 | 50 | 5.8 | 46.7 |
| 20 | BEALL | TRACY | 50 | 8.2 | 26 | 5.8 | 44 | 8.4 | 32 | 2.6 | 60 | 4.4 | 58 | 8.6 | 75 | 8.6 | 46.6 |
| | AVERAGE VALUES = | | 60 | | 45 | | 50 | | 36 | | 81 | | 69 | | 72 | | 57 |
| | STANDARD DEVIATIONS = | | 8 | | 26 | | 10 | | 26 | | 16 | | 11 | | 11 | | 7 |

# EXPLANATION OF IMPROVEMENTS

The recommended improvements presented within this report are short term improvements which reflect the minimum amount of upgrading or modifications necessary to increase driver expectancy and to update the sites to current standards. Long term improvements are only considered viable when severe conditions at the site prevent short term improvements from completely satisfying the control measures necessary to significantly reduce future problems. Since any long term improvements would be dependant upon significant changes in future traffic operations and most of the sites of this nature are covered by the transportation plan, no specific plans were advanced and no costs or project ranking was completed for long term improvements. However, general recommendations of a long term nature are made within the site specific section when applicable.

Some of the recommended improvements have sufficient latitude so that alternative measures could be suggested during design. The selection of recommended improvements was based on subjective engineering judgement and current traffic control standards. Basis of the recommendations incorporate an understanding of driver psychology, visual input requirements, accident statistics and comparative studies. Some of the recommended improvements may not be directly related to accident prevention, but are required to meet current standards and provide consistent control measures. Specific reasons for recommendations are presented in the site specific section of this report.

Prior to subjecting the proposed improvements to review based on the status quo, it should be remembered that these study sites are probably not characteristic of all Bozeman intersections. They have been documented as the highest accident locations in the City, with exception of federal aid designated streets. As such, they require improvement measures not typical of other area intersections. If recommended improvements call for 36" stop signs and centerline striping, it should not be considered as justification for installing larger stop signs or striping centerlines at all other locations. In most cases, 30" stop signs are completely adequate while in

some cases, either because of sight restrictions; visual distractions on the horizon; lighting conditions or other various reasons, stop signs are simply not perceived by the driver. Recommendations for oversize stop signs in this study are made when a visual obstruction is not apparent but there is strong evidence that the stop sign is not being perceived.

Since all of the study sites are recognized accident cluster locations, there is good statistical probability that the majority of accidents are not by chance. Therefore, street and traffic control conditions are likely deficient for expected traffic operations. Some of the deficiencies are entirely obvious once the facts have been examined. Others defy a clear cut answer with regard to cause and effect relationships. In all cases, improvements are geared toward improving the street system by relating to the driver's cognitive abilities. The first means of accomplishing this is to enhance visual perception by insuring a clear line of sight to all important information sources, ie. approaching vehicles and traffic control devices. The second factor related to driving functions is directed at sub-conscious perception, which is the major factor in driver expectancy. As an example, if a street section appears to be a thru street based on visual clues such as wide pavement surfaces, minor side street traffic and an uninterrupted view to the horizon, even over-sized stop signs may be ignored. In this case, disruption of the pattern is required. It may take the form of a stop bar, cross walk or centerline striping at a stop controlled intersection. These are all methods of giving visual clues to the driver which subconsciously indicates that the approaching intersection requires actions different than did the previous intersections. Many of the recommended improvements within this study relate to the later means of providing information to the driver.

Recommendations for plastic pavement markings are replete throughout the study. Painted marks may be substituted to substantially reduce the City's cost. However, more intense maintenance will be needed if this alternative is chosen. If the marks are worn most of the time, they will not functioned as planned.

In one case, a yield sign is recommended rather than a stop sign. There are many factors influencing this decision. The most important factor is sight distance. If there is a permanent sight obstruction such as a building, yield signs are not considered because their use assumes ability to perceive and react to a potential conflict similar to an uncontrolled intersection. When permanent sight obstructions do not exist, all mobile obstructions (parked vehicles) must be moved from the clear vision zone and yield signs can then be recommended as a first level improvement. Bozeman has proven to be quite unique in this regard. Low traffic volumes at several other intersection within this study could easily be controlled by yield signs if were not for permanent sight obstructions consisting of houses and other buildings. The minimum required sight distance for vehicles traveling at 25 mph entering an uncontrolled intersection is 110 feet on all approach legs. The same distance is required for yield controlled intersections. When these minimum distances cannot be achieved, yield control is not an option. In the case of this study, all intersections which cannot meet the minimum sight distance requirements must necessarily be upgraded to a stop condition. Therefore, almost all recommendations include installation of stop signs.

Judging from street system characteristics in Bozeman, most intersections would require stop control. This does not mean that the city should install stop signs at every intersection. Other conditions may exist throughout the remainder of the city which would preclude the use of stop signs. The study sites happen to be known problem areas for which extra measures need to be implemented.

From discussions with city personnel and residents, there appears to be a perception that stop signs are undesirable because they create thru streets. In some cases, this perception may be correct. However, traffic demand must initially be present before stop control could affect traffic patterns to any extent and side street stop control must be implemented extensively along a street to affect travel times to any degree. In the same vein, stop signs should never be used to prevent a street from being utilized as a thru route. Installation of stops signs on the higher volume leg of an intersection does not effectively reduce travel time and only

serves to create disrespect for the sign and increases accidents. Within this study all attempts were made to coordinate stop signs with existing stop signs in the surrounding area, but volumes and function were primary considerations in the recommended locations. When volumes and functions were approximately equal on all legs, potential vision conflicts were used to decide stop sign location.

The improvement sketches, in some cases should not be considered design plans. Some of the more complex drawings are preliminary and are intended to present improvement concepts only in enough detail to provide the measure of control necessary and to provide cost estimates. In some cases, detailed survey data; design analysis; design plans and specifications; and construction layout will be necessary to effectively achieve the improvements.

# BENEFIT/COST RATIOS

## COSTS

Preliminary cost estimates are developed by applying unit costs to required quantities based either on current prices as tabulated from average bid prices of similar projects or, where applicable, on prices established by Montana Department of Transportation's Project Planning Section. The costs should in no way be considered a quote or final estimate of actual work.

The following are traffic control devices and allowable costs that are eligible for funding by the Montana Department of Transportation through their Off-System Safety Program:

A. Signs:

1. 1 square foot to 6 square feet - $ 100.00
2. 6.1 square feet to 10 square feet - $ 140.00
3. 10.1 square feet to 20 square feet - $ 170.00
4. supplementary sign on same post - $ 50.00

B. Delineators:

1. Design ""A" metal posts - $ 9.25
2. Design "A" flexible posts-6' - $ 20.00
3. Design "A" flexible posts-27" - $ 6.00

C. Guardrail:

1. New "W" Beam rail (per foot) - $ 8.00
2. "W" Beam end treatment (each) - $ 1,000.00
3. New concrete rail (per foot) - $ 16.00
4. New concrete end tapers (per foot) - $ 16.00

D. Pavement Markings:

1. Pavement Marking Paint (per gal) - $ 15.00
*2. Pavement Marking Plastic (per S.F.) - $ 3.00
*3. Plastic Words & Symbols (per S.F.) - $ 2.00

The Department of Justice and the Montana Department of Transportation are currently evaluating safety improvement costs within urban environments. Since the above noted items do not adequately correlate with the nature of improvements within highly urbanized areas, other funding schemes are now being considered. The plastic pavement marking costs*, listed above, are only an estimate based on current unit bid prices and have not been formally established by MDoT.

Even though Bozeman street and traffic crews are capable of performing a good deal of work, costs related to physical changes in the roadway section are based on contract prices in order to correlate with costs requiring contract bid letting. The costs do not include administrative, engineering or field layout for the recommended improvements at sites which would require final design plans. Engineering design will generally be required to produce contract plans and specifications. These costs should be evaluated prior to planning improvement projects requiring bids.

## BENEFITS

Estimated benefits are made by applying accident reduction forecasts based on the type of improvement recommended. The forecasts are based on the subjective evaluation by an experienced traffic engineer. This evaluation is aided by knowledge of accident experience at similar locations with the improvements existing. Also statistical studies relating certain improvements to accident reduction are used as a guide ie, Roy Jorgenson and Associates, *"Evaluation of Criteria for Safety Improvements on the Highway" (Washington, D.C.: U.S. Bureau of Public Roads, Office of Highway Safety, 1966. p. 316).*

The forecasted reduction is expressed as a percentage of each type of accident. This percentage is multiplied by the percentage of all accidents represented by each type. The total percent reduction of all accidents at each site is the sum of all accidents reduction percentages for each type.

The method used to compute benefits in this study follows the Montana Department of Transportation's procedures. Those procedures were programmed by Marvin & associates for Quattro Pro Computer Software which provides a tabular summary of all variables in the computation.

If applied consistently, the economic benefit computation will provide a realistic estimate of average economic savings to society. The benefit amount should not be interpreted as a dollar value that Bozeman will receive as a result of dollar outlay. It is a figure used to quantify the economic benefit to society that would occur if a certain number of accidents did not occur.

## B/C RATIO

The B/C provides a numerical reference to the relative value of the recommended improvements. It is the desire of any improvement project to have a benefit-cost (B/C) ratio in excess of 1.0. If the B/C is less than 1.0 the project would have questionable justification. In this study, none of the sites had a B/C less than one.

Table 11 is a computer generated summary of the B/C ranking for the twenty five study sites. From this table, it can be seen that the total capital cost of improvements would be approximately $ 46,000 or about $2,300 per site. The total projected benefit would be approximately $ 172,000, annually. The average B/C ratio value was computed to be approximately 24, which translates into a 2400% return on investment.

B/C indicator values ranged between 12 and 97. The average value for all sites was 55. An explanation of the B/C indicator value is given in the priority index section of this report.

## TABLE 11. SITE RANKING BY BENEFIT/COST RATIOS

| RNK # | SITE LOCATION | | PROJ LIFE | CAPITOL COST IMPROVE | EQUIV ANNUAL COST | ANNUAL MAINT. COST CH. | TOTAL ANNUAL COST | Q | Afi | Apd | PFI | Ppd | ANNUAL BENEFIT | B/C RATIO | IND VAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | COSTS | | | | BENEFITS | | | | | | | |
| 1 | STORY | FIFTH | 5 | $410 | $108 | $41 | $149 | $18,150 | 1.00 | 2.00 | 60% | 60% | $12,944 | 86.78 | 97 |
| 2 | BABCOCK | YELLOWSTONE | 5 | $730 | $193 | $73 | $266 | $18,150 | 2.00 | 0.50 | 50% | 50% | $18,896 | 71.15 | 93 |
| 3 | HAYES | THIRD | 5 | $760 | $200 | $76 | $276 | $18,150 | 1.50 | 1.50 | 60% | 60% | $18,039 | 65.24 | 91 |
| 4 | CURTISS | TRACY | 5 | $1,340 | $353 | $134 | $487 | $18,150 | 2.50 | 2.00 | 53% | 60% | $26,366 | 54.09 | 87 |
| 5 | OLIVE | SEVENTH | 5 | $760 | $200 | $76 | $276 | $18,150 | 1.25 | 1.00 | 60% | 60% | $14,803 | 53.54 | 86 |
| 6 | PEACH | BOZEMAN | 5 | $1,105 | $291 | $111 | $402 | $18,150 | 1.25 | 0.50 | 60% | 30% | $14,114 | 35.11 | 77 |
| 7 | LAMME | FIFTH | 5 | $845 | $223 | $85 | $307 | $18,150 | 0.75 | 1.25 | 40% | 50% | $6,510 | 21.18 | 66 |
| 8 | ARTHUR | THIRD | 5 | $1,110 | $293 | $111 | $404 | $18,150 | 0.50 | 1.00 | 60% | 60% | $6,472 | 16.03 | 60 |
| 9 | KOCH | THIRD | 5 | $775 | $204 | $78 | $282 | $18,150 | 0.25 | 1.25 | 60% | 40% | $3,542 | 12.56 | 55 |
| 10 | VILLARD | FIFTH | 5 | $1,100 | $290 | $110 | $400 | $18,150 | 0.25 | 2.25 | 60% | 60% | $4,842 | 12.10 | 54 |
| 11 | VILLARD | TRACY | 5 | $1,211 | $319 | $121 | $441 | $18,150 | 0.25 | 1.25 | 60% | 56% | $3,848 | 8.73 | 47 |
| 12 | TAMARACK | FIFTH | 5 | $3,530 | $931 | $353 | $1,284 | $18,150 | 0.75 | 1.00 | 60% | 50% | $9,096 | 7.08 | 43 |
| 13 | BEALL | FIFTH | 5 | $1,240 | $327 | $124 | $451 | $18,150 | 0.50 | 0.75 | 25% | 23% | $2,578 | 5.71 | 38 |
| 14 | MENDENHALL | TENTH | 5 | $2,010 | $530 | $201 | $731 | $18,150 | 0.25 | 2.00 | 60% | 41% | $4,032 | 5.51 | 37 |
| 15 | OLIVE | BOZEMAN | 5 | $1,980 | $522 | $198 | $720 | $18,150 | 0.25 | 1.25 | 60% | 52% | $3,771 | 5.24 | 36 |
| 16 | HAYES | FIFTH | 5 | $330 | $87 | $33 | $120 | $18,150 | 0.00 | 1.25 | 0% | 30% | $574 | 4.78 | 34 |
| 17 | OLIVE | TRACY | 12 | $9,090 | $1,334 | $300 | $1,634 | $18,150 | 0.50 | 2.25 | 60% | 57% | $7,516 | 4.60 | 33 |
| 18 | OLIVE | BLACK | 12 | $11,060 | $1,623 | $306 | $1,929 | $18,150 | 0.75 | 2.75 | 40% | 51% | $7,700 | 3.99 | 30 |
| 19 | BEALL | TRACY | 5 | $2,787 | $735 | $279 | $1,014 | $18,150 | 0.25 | 1.00 | 60% | 60% | $3,695 | 3.64 | 28 |
| 20 | GARFIELD | WILLSON | 5 | $4,235 | $1,117 | $424 | $1,541 | $18,150 | 0.25 | 2.00 | 30% | 43% | $2,704 | 1.76 | 12 |
| | TOTALS : | | | $46,408 | $9,884 | $3,232 | $13,116 | $363,003 | | | | | $172,042 | | |
| | AVERAGES : | | 5.7 | $2,320 | $494 | $162 | $656 | | | | 51% | 50% | $8,602 | 23.94 | 55.21 |

# PRIORITY INDEX

The ranking of site improvement priorities cannot be directly dependent on the hazard ranking of the study sites. The value of the improvements must enter into the priority listing in the form of the benefit/cost ratio (B/C). The method of developing a composite Hazard Index - B/C listing must be dependent on the relative index scale used in the hazard index computation. Therefor, a correlation of scale between the B/C ratio and hazard indicator value was developed on the following assumptions:

1. The contributing conditions creating hazards at each site and the resulting hazard ranking is relatively independent of the cost of correcting these conditions.
2. Benefits to be derived from correcting hazardous situations at each site is indirectly proportional to the degree of hazards encountered.
3. The benefit/cost ratio, by virtue of benefit computation, is indirectly proportional to the number of accidents indicator and severity indicator, both of which are curvilinear functions.
4. The benefit/cost ratios can be rated on a scale of 0 to 100 based on a curvilinear function.
5. The B/C ratio of 1.0 is equivalent to an indicator value of 0 and the upper limit (indicator value = 100) must be chosen to encompass the majority of sites.

In this case, a B/C of 100.0 and above assumes the indicator value of 100. Based on these assumptions a graphic plot of the B/C ratio versus B/C indicator value has been established and it is shown in Figure 13. Since it has been graphed on semi-log paper the line appears linear.

Since the relative weighting of benefit/costs and hazard indexes is a controversial subject which would require research beyond the scope of this report, it is felt that the priority index should be based on 33% weighting for the benefit-cost ratio and 67% weight on the hazard index. Therefore, to establish a priority index the following formula has been devised:

*Priority Index = (Hazard Index) x (0.67)*
*+ (Benefit/Cost Indicator) x (0.33)*

Table 12. is the computer generated summary of priority ranking based on the composite hazard index - benefit/cost index values.

## TABLE 12. SITE RANKING BY PRIORITY INDEX - SUMMARY

| PRIORITY NUMBER | AVENUE | STREET | HAZARD INDEX | WEIGHTED VALUE | BEN/CO INDEX | WEIGHTED VALUE | PRIORITY INDEX |
|---|---|---|---|---|---|---|---|
| 1 | STORY | FIFTH | 68.40 | 45.83 | 97 | 32.01 | 77.84 |
| 2 | HAYES | THIRD | 68.50 | 45.90 | 91 | 30.03 | 75.93 |
| 3 | CURTISS | TRACY | 67.40 | 45.16 | 87 | 28.71 | 73.87 |
| 4 | OLIVE | SEVENTH | 60.50 | 40.54 | 86 | 28.38 | 68.92 |
| 5 | BABCOCK | YELLOWSTONE | 51.80 | 34.71 | 93 | 30.69 | 65.40 |
| 6 | LAMME | FIFTH | 57.50 | 38.53 | 66 | 21.78 | 60.31 |
| 7 | PEACH | BOZEMAN | 51.10 | 34.24 | 77 | 25.41 | 59.65 |
| 8 | ARTHUR | THIRD | 59.00 | 39.53 | 60 | 19.80 | 59.33 |
| 9 | KOCH | THIRD | 57.80 | 38.73 | 55 | 18.15 | 56.88 |
| 10 | VILLARD | FIFTH | 57.10 | 38.26 | 54 | 17.82 | 56.08 |
| 11 | TAMARACK | FIFTH | 57.70 | 38.66 | 43 | 14.19 | 52.85 |
| 12 | OLIVE | TRACY | 62.60 | 41.94 | 33 | 10.89 | 52.83 |
| 13 | OLIVE | BLACK | 62.20 | 41.67 | 30 | 9.90 | 51.57 |
| 14 | VILLARD | TRACY | 52.60 | 35.24 | 47 | 15.51 | 50.75 |
| 15 | MENDENHALL | TENTH | 54.10 | 36.25 | 37 | 12.21 | 48.46 |
| 16 | BEALL | FIFTH | 50.40 | 33.77 | 38 | 12.54 | 46.31 |
| 17 | OLIVE | BOZEMAN | 49.60 | 33.23 | 36 | 11.88 | 45.11 |
| 18 | HAYES | FIFTH | 46.70 | 31.29 | 34 | 11.22 | 42.51 |
| 19 | BEALL | TRACY | 46.60 | 31.22 | 28 | 9.24 | 40.46 |
| 20 | GARFIELD | WILLSON | 54.30 | 36.38 | 12 | 3.96 | 40.34 |

| | | | | |
|---|---|---|---|---|---|
| AVERAGE VALUES : | 56.80 | 38.05 | 55.20 | 18.22 | 56.27 |
| STANDARD DEVIATIONS : | 6.54 | 4.38 | 24.93 | 8.23 | 11.17 |

PRIORITY INDEX = (HAZARD INDEX x 0.67) + (BENEFIT/COST INDEX x 0.33)

# IMPLEMENTATION

Within Table 13, the priority lists have been arranged in a manner in which budget considerations can readily be applied in the decision to proceed with improvements. Priority ranking was the major consideration in selecting which sites will be receiving funds first. Since limited funds are available, it is usually necessary to skip over a few higher priority projects to improve a greater number of sites as soon as possible. The listing assumes that eligible project costs will be funded by MDoT Off-system Safety funds. In the past MDoT project funding limit was less than $10,000 per project period, or else formal bid letting procedures were required by MDoT. This dollar figure was used as the criteria to define construction groupings. At this time, MDoT is in the process of deciding how these project will be funded, designed and constructed in the future. In this case, it would be futile to attempt scheduling of individual projects until new policies have been set.

There is no timetable given for these improvements and it may be conceivable that MDoT could fund most of the sites in a single years period, depending on available funding. The city will want to request funding from MDoT by submitting this report to Dave Johnson, P.E., Preconstruction Engineer.

## TABLE 13. PROJECT IMPLEMENTATION COST SCHEDULE

| PRIORITY NO. | | AVENUE | COST ESTIMATE | MDoT ELIGIBLE FUNDS | CITY FUNDS |
|---|---|---|---|---|---|
| 1 | STORY | FIFTH | $410 | $260 | $150 |
| 2 | HAYES | THIRD | $760 | $660 | $100 |
| 3 | CURTISS | TRACY | $1,340 | $1,240 | $100 |
| 4 | OLIVE | SEVENTH | $760 | $660 | $100 |
| 5 | BABCOCK | YELLOWSTONE | $730 | $730 | $0 |
| 6 | LAMME | FIFTH | $845 | $645 | $200 |
| 7 | PEACH | BOZEMAN | $1,105 | $1,085 | $20 |
| 8 | ARTHUR | THIRD | $1,110 | $860 | $250 |
| 9 | KOCH | THIRD | $775 | $775 | $0 |
| 10 | VILLARD | FIFTH | $1,100 | $1,100 | $0 |
| 11 | TAMARACK | FIFTH | $3,530 | $2,215 | $1,315 |
| 12 | OLIVE | TRACY | $9,090 | $4,660 | $4,430 |
| 13 | OLIVE | BLACK | $11,060 | $1,760 | $9,300 |
| 14 | VILLARD | TRACY | $1,211 | $1,011 | $200 |
| 15 | MENDENHALL | TENTH | $2,010 | $1,900 | $110 |
| 16 | BEALL | FIFTH | $1,240 | $1,150 | $90 |
| 17 | OLIVE | BOZEMAN | $1,980 | $1,670 | $310 |
| 18 | HAYES | FIFTH | $330 | $230 | $100 |
| 19 | BEALL | TRACY | $2,787 | $2,052 | $735 |
| 20 | GARFIELD | WILLSON | $4,235 | $4,185 | $50 |
| TOTAL CONSTRUCTION COSTS = | | | $46,408 | $28,848 | $17,560 |

# STREET CORRIDORS

As previously mentioned, several street corridors have consecutive accident cluster areas which would appear to be corridor related.

**Olive Street** - between Willson and Bozeman has experienced 42 accidents at four consecutive intersections during the study reporting period. Three of the intersection, Tracy, Black and Bozeman, are included as individual study sites. All three intersections have distinctly different conditions requiring individualistic improvements. The only corridor related improvements beyond those recommended in the individual site sections, that may be considered, would be elimination of parking and possible improvements to the intersection with Willson. Traffic signal warrants at Willson and Olive are within 25% of being met. A more detailed warrant analysis and geometric investigation is recommended at that intersection. Recommended improvements at the other Olive Street intersections should provide excellent short term improvements along this corridor.

**North Fifth Avenue** - between Mendenhall And Tamarack Streets has experienced 38 accidents at six separate intersections during the four year reporting period. Four of the six intersections in this corridor are included as individual study sites. Those four intersections: Lamme, Beall, Villard and Tamarack, also have distinct conditions unique to the accidents that have been experienced. Implementation of these alternatives will also provide excellent short term solutions to the majority of this corridor's accident problems. However, one common condition exists at all of the corridor locations. All intersections on North Fifth Avenue are one block east of N. 7th Avenue, which is a major north-south arterial providing a direct link between Interstate 90 and Main Street. The only east-west thru streets east of N. 7th between Interstate 90 and Main, are Tamarack and Peach. Both of these streets are two lane facilities and neither of their intersections with N. 7th are signalized. Because of the thru street spacing, travel speeds and related north-south access conditions, east west traffic filters through most of the east-west streets to gain access to N. 7th. This situation creates higher traffic volumes on the east-west

streets than would normally be expected. A large portion of N. Fifth traffic is circulation and overflow traffic from N. 7th. The overflow traffic is using N. Fifth to access various developments along N. 7th which would otherwise be difficult to access because of congestion or turn restrictions caused by the raised median in N. 7th.

Both directions of traffic at the N. Fifth intersections are essentially taking a shortcut and drivers are necessarily intent on proceeding unimpeded. When they enter the uncontrolled intersections with Fifth, each direction assumes the right-of-way. This situation is especially true for westbound traffic, since drivers are approaching the major intersection with N. 7th and naturally tend to drive the intersection ahead rather than focus on the immediate intersection. This factor was important in determining control at two of the study intersection locations which are currently uncontrolled.

If the individual site recommendations are implemented all of the intersections with Fifth would be stop controlled on the Fifth Avenue approaches. This appears to be a desirable action since it will tend to reduce traffic on Fifth to a small degree and it will not change the traffic demand on the east-west streets to any extent.

Long term improvements will be realized when the Nineteenth Avenue interchange is completed, reducing N. 7th traffic congestion. Also, future improvements to Tamarack Peach and Willson would reduce demand for east-west traffic using local streets.

**University Access** - has been a problem for many years, probably even before the existing street system was in place. As the MSU Campus has grown and new buildings constructed, the need to interrupt the city street grid system increased. Today, many of the streets which used to traverse the campus have been closed and parking lot construction has not entirely kept up with demand. As a result of past and future closures (being proposed), the core area of the campus is not accessible by automobile. Students and staff fill available fringe parking areas and the remainder park on adjacent streets, mostly to the east and south of the campus. In addition, apartments, fraternity and sorority houses exist in this area, which

fill every legal and illegal on-street parking space. The local residential streets would have low traffic volumes except that every vehicle that uses the streets for parking must also arrive and depart, usually at the same time. This situation creates a breeding ground for accidents.

Figure 14. is a map of the Montana State University area with the location and number of accidents at street intersections. This map does not include any streets north of College, west of Eleventh, east of Willson or south of Grant. It also does not include intersections with less than 3 accidents nor accidents at non-intersection locations. The total number of intersections accidents noted on this map is 169, during the four year reporting period. It is estimated that over 200 accidents could be identified if minor intersection and midblock accidents were included. It is also estimated that there were 80 injuries involved with these 200 accidents. Statistically, the economic loss realized due to accidents during the four year reporting period within this quarter section of land was approximately 1.2 million dollars. Even if only 40% of these accidents could be eliminated, some very significant street and parking facilities could be justified, economically.

A number of improvements have been set forth in the new transportation plan which would purportedly improve access and safety within the university area. The basic concept would be development of a boundary road system using Kagy, S. 19th and College and blocking off most internal campus roads. Unfortunately no specific recommendations were set forth to define an eastern boundary road which, according to the data contained in this study, is the most critical in terms of safety.

Four of the intersection on the eastern side of the university were included as specific study sites. Recommendations included stop and, in one case yield, control with elimination of numerous on-street parking spaces. These recommendations, when implemented and combined with parking enforcement, will undoubtedly reduce accidents at these intersections significantly. Unfortunately, there are at least 35 additional intersections which have similar conditions that could potentially become accident cluster sites in the future. Without more detailed study, no short term solutions could be made at all the additional intersections. However, it would be recommended that the city evaluate all of these intersections for sight distance

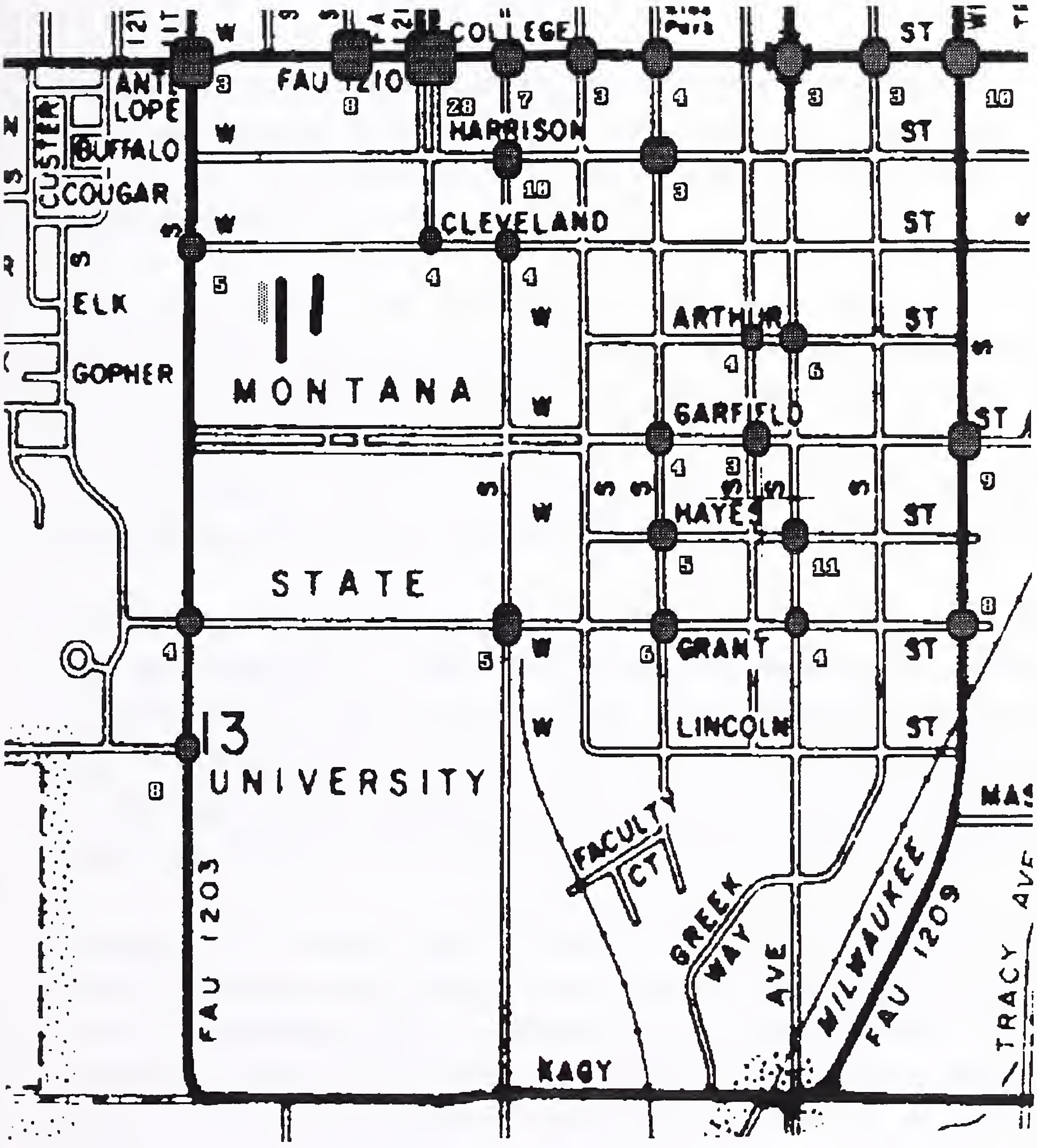



**FIGURE 14. UNIVERSITY AREA INTERSECTION ACCIDENTS**

and perform necessary improvements such as trimming trees and bushes and marking no parking zones at the corners with yellow curb paint. Very little can be done about houses and structures which are located within the required sight triangle other than to evaluate the need for stop control.

Long term solutions to these problems would include construction of a collector street sufficient to provide uninterrupted access to adequate campus parking facilities on the east side of the campus. The collector street should intersect Willson at a signalized intersection and provide the shortest travel time of all possible routes. Additional campus parking facilities when combined with the proposed residential parking permit area should relieve stress imposed on the residential area.

The transportation plan also proposes a raised median on Willson to prevent access and circulation from Willson through the area neighborhoods. While the concept may appear feasible, further analysis of the implications may be warranted prior to implementing such a drastic action since no restrictions would be provided to southbound traffic accessing the side streets and outbound university traffic may merely use north-south local streets to gain access to Willson at a median opening.

Because of the complex nature of safety problems and transportation efficiency within the university area and the need to have a fully coordinated street system plan, it is recommended that a complete study of university access and traffic circulation be initiated. While some elements have already been proposed, it is not known whether a comprehensive transportation plan for the university area has been completed.

# PROGRAM CONTINUATION

Since the basic format of the study has been outlined and an initial priority list established, continuance of this program or a similar program is strongly advised. The findings and recommendations of this study will soon become obsolete without continued updating at least on an annual basis. The following recommendations for continuance of the program are offered to the City of Bozeman:

1. The City Engineer's office should receive accident reports from the Police Department.
2. One person should be assessed with the responsibility of the program to insure that all data is being supplied and processed.
3. An agreement with the City Police Department should be made which would modify computer reporting to identify cluster sites or a separate program should be used to store basic data from the police reports as they are received by the Engineer's office.
4. Criteria should be developed for the inclusion of additional sites to be analyzed, such as number of accidents, accident rate and severity.
5. Coordinate existing traffic counting programs to include areas that may not currently be covered. With broad enough coverage, estimates of volumes on all street segments can be made for screening purposes.
6. Analyze new sites according to all or selected procedures of this study and include them in the priority list when warranted.

All of the data processing and storage can be handled by most computer spreadsheet software programs. A copy of the data disk has been provided to the City of Bozeman. If translation problems occur between these data files and the City's spread sheet program, they can be translated to a ASCII file upon request.

# REPORT

# FIGURES

## HAZARD

## INDICATOR

## VALUES

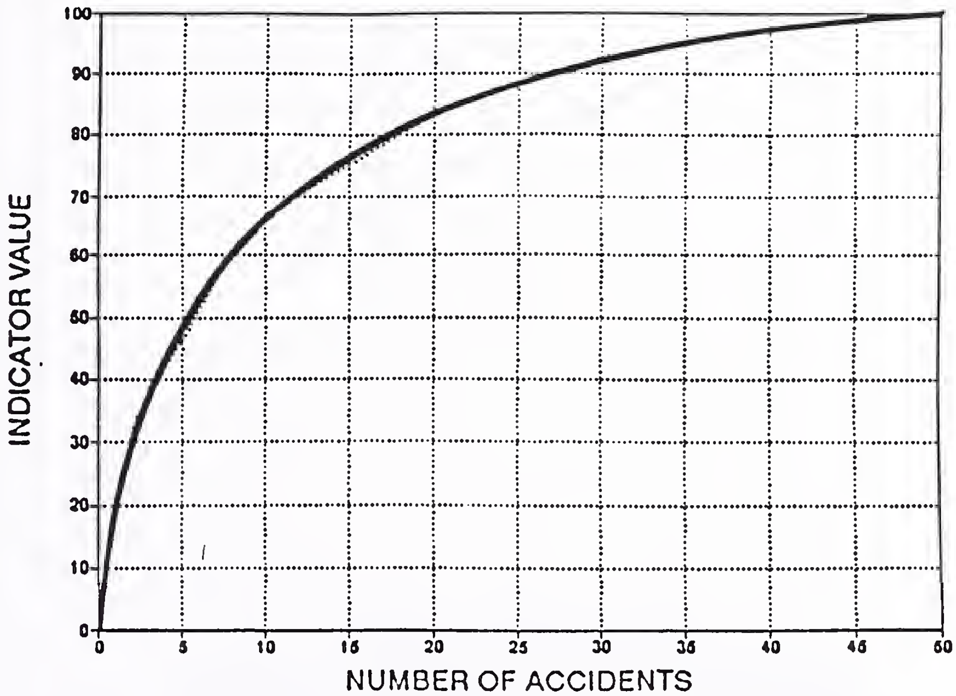



FIGURE 6 NUMBER OF ACCIDENTS INDICATOR

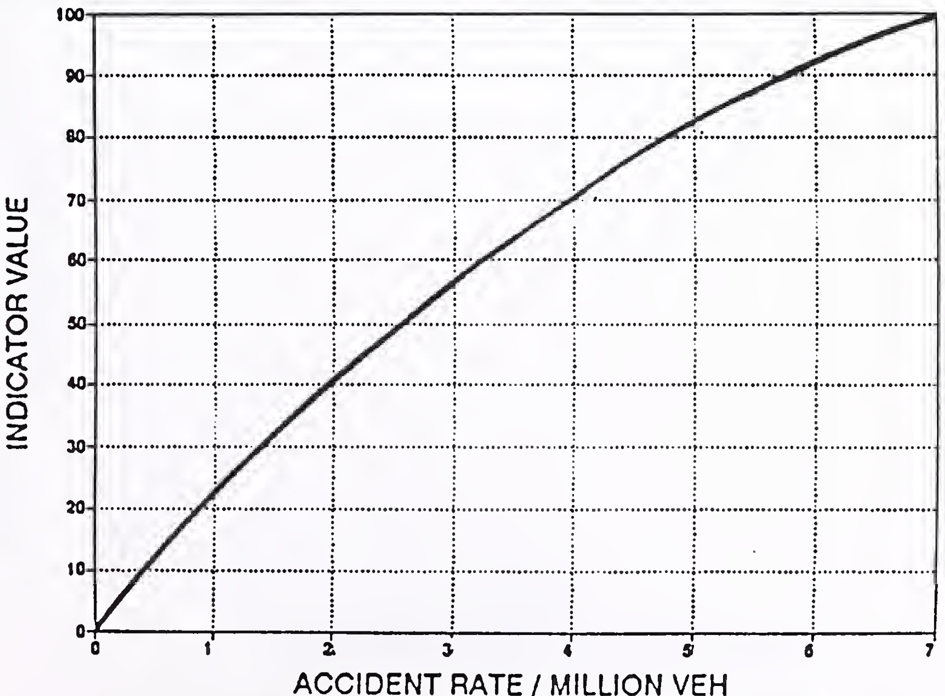



FIGURE 7 ACCIDENT RATE INDICATOR

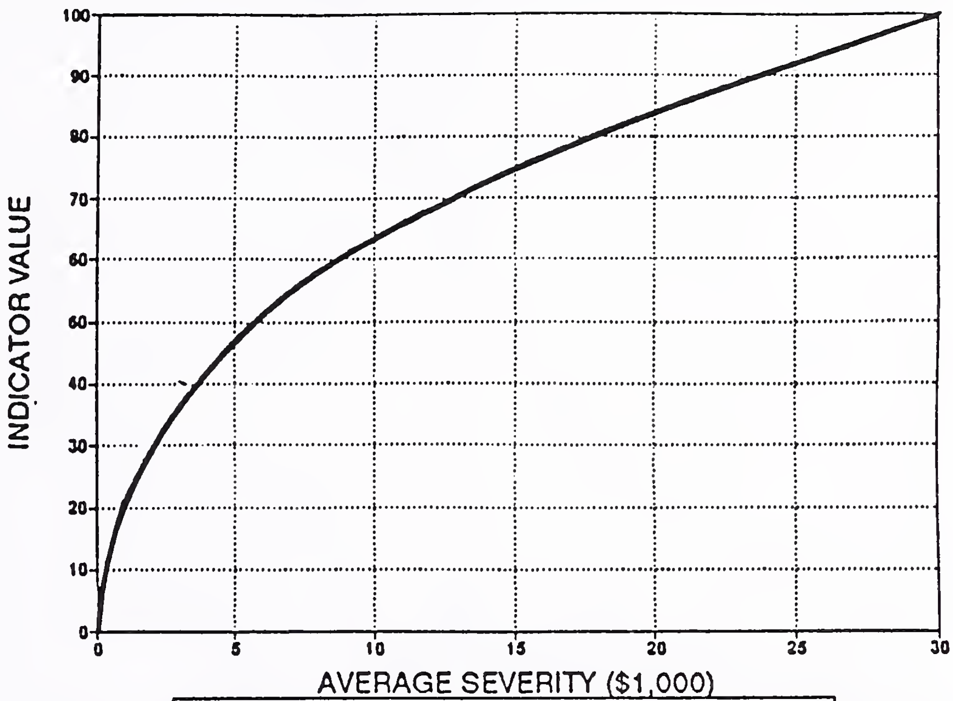



FIGURE 8 ACCIDENT SEVERITY INDICATOR

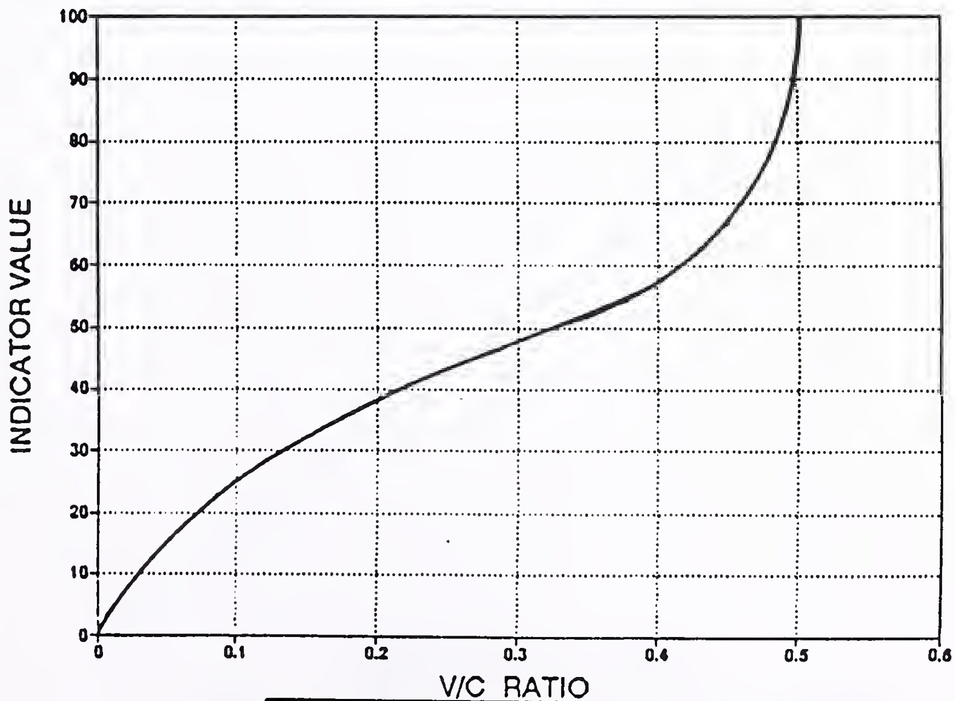



FIGURE 9 V/C RATIO INDICATOR

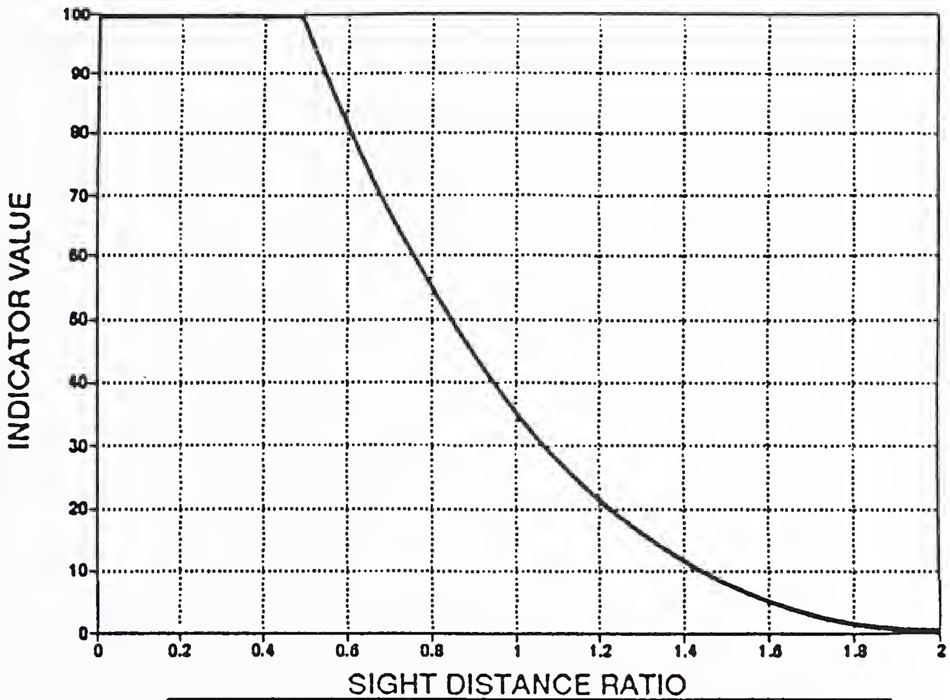



FIGURE 10 SIGHT DISTANCE RATIO INDICATOR

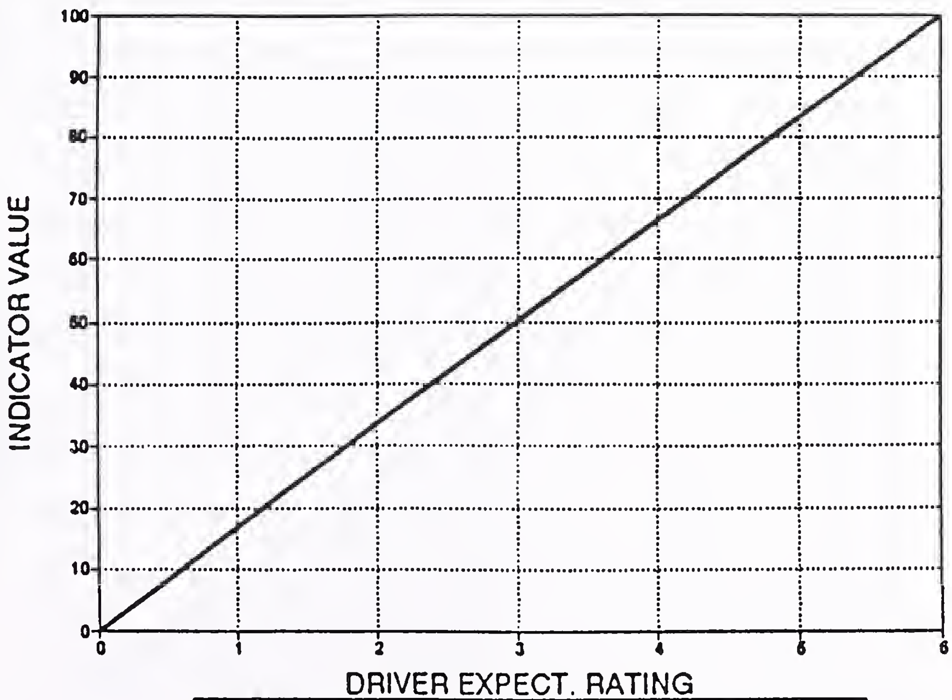



FIGURE 11 DRIVER EXPECTANCY INDICATOR

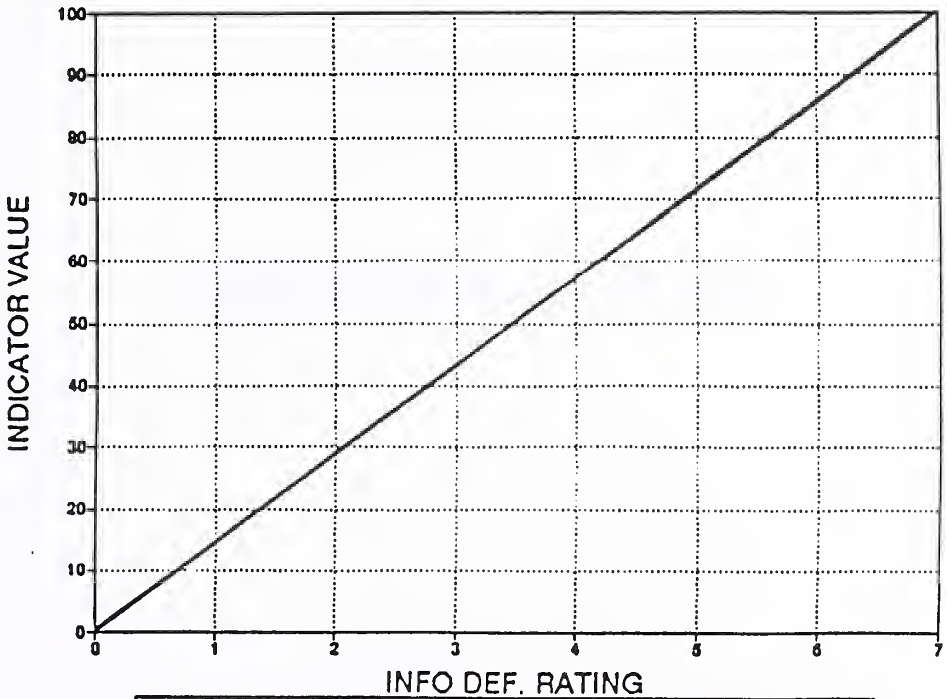



FIGURE 12 INFORMATION DEFICENCY INDICATOR

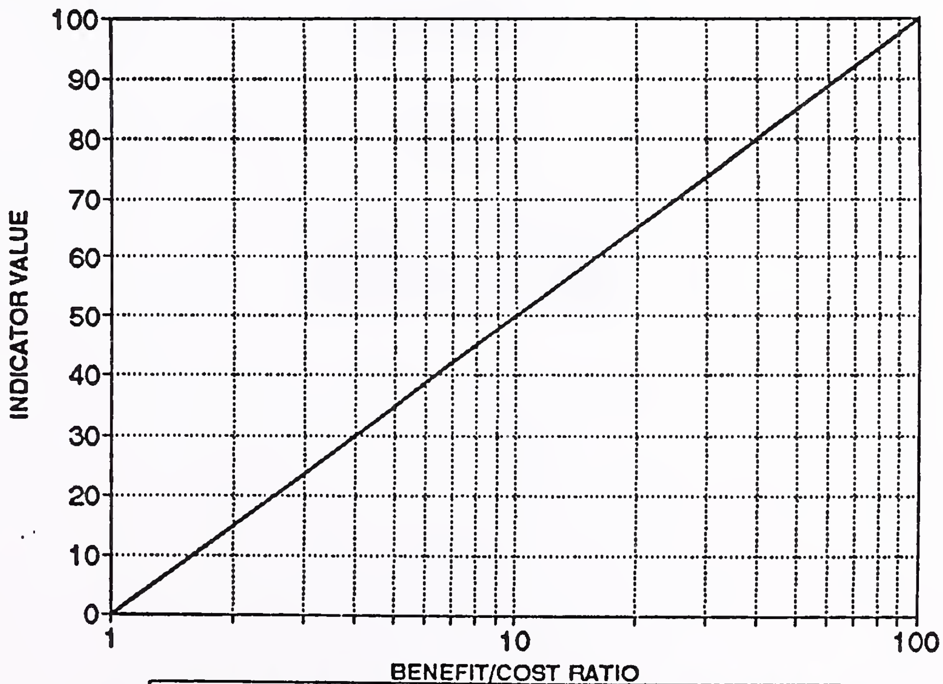



FIGURE 13. BENEFIT/COST RATIO INDICATOR

# INDIVIDUAL SITES

# SPECIFIC

# DATA

# &

# ANALYSIS

# SITE

# NUMBER

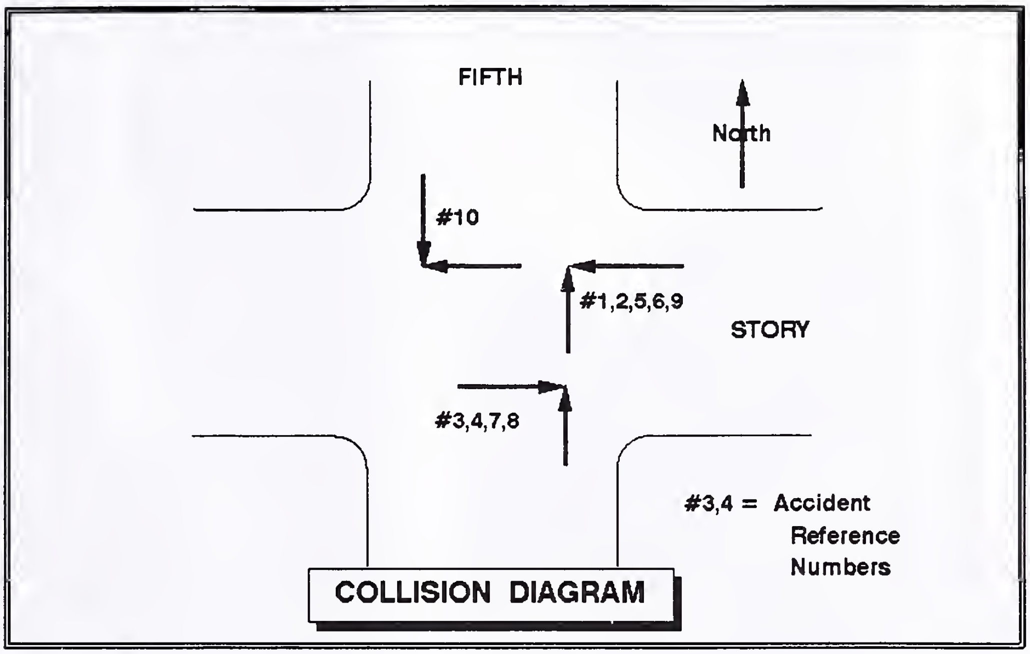
# 1

# STORY

# and

# FIFTH

# ACCIDENT SUMMARY
## STORY & FIFTH




| ACC NO. | ACCIDENT TYPE | ACCIDENT KEY | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
| 1 | ANGLE | 7 | 17 | 88 | 1415 | PROP DAM | CLEAR | DRY | DAY |
| 2 | ANGLE | 11 | 14 | 88 | 905 | PROP DAM | CLEAR | SNOW | DAY |
| 3 | ANGLE | 12 | 5 | 88 | 1440 | PROP DAM | CLEAR | ICY | DAY |
| 4 | ANGLE | 5 | 17 | 89 | 2100 | PROP DAM | CLEAR | DRY | DAY |
| 5 | ANGLE | 11 | 17 | 89 | 1248 | INJURY | CLEAR | DRY | DAY |
| 6 | ANGLE | 4 | 5 | 90 | 2030 | INJURY | CLEAR | DRY | DAY |
| 7 | ANGLE | 12 | 18 | 90 | 1824 | PROP DAM | CLEAR | ICY | NITE |
| 8 | ANGLE | 1 | 10 | 91 | 1525 | PROP DAM | CLEAR | SNOW | DAY |
| 9 | ANGLE | 1 | 18 | 91 | 1610 | PROP DAM | CLEAR | WET | DAY |
| 10 | ANGLE | 10 | 31 | 91 | 1456 | PROP DAM | SNOW | SNOW | DAY |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

### ACCIDENT STATISTICS

| NO. ACC. | YEAR | | | |
|---|---|---|---|---|
| 3 | 1988 | #INJ ACC | 2 | |
| 2 | 1989 | #FAT ACC | 0 | |
| 2 | 1990 | #PDO ACC | 8 | |
| 3 | 1991 | PERSON = | 4 | * |
| 10 | TOTAL | NIGHTIME | 10% | |

*** No. of Persons Injured**

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 10 | DRY | 40% |
| REAR END | 0 | WET | 10% |
| SIDESWIPE | 0 | SNOW | 30% |
| LEFT TRN | 0 | ICE | 20% |
| OTHER | 0 | OTHER | 0% |

Looking North From East Leg

Looking South

FIFTH

Looking East

Looking West

STORY

## TRAFFIC OPERATIONS

Story Street is a local east-west and Fifth Avenue is a local north-south street. Their intersection is in the middle of an older residential area of Bozeman. The intersection appears to be typical of other intersections in the area. Street widths are approximately 32 feet. Both streets have tree lined boulevards with large deciduous trees. Parking is allowed on both sides of the street. Traffic volumes on Fifth are very low, while Story Street has about double the volume at 500 vehicles per day.

A cluster of Pine trees on private property in the northeast corner of the intersection presents an obvious sight obstruction. Narrow street right-of-way and inadequate building setbacks at this intersection are typical of many Bozeman intersections. On-street parking appears to be moderate on the approach streets. The required sight distance for an uncontrolled intersection and 25 mph vehicle operating speeds is 110 feet. It was determined that a house in each corner of this intersection encroaches upon the sight triangle required for an uncontrolled intersection. While it was difficult to determine definite traffic operational characteristics at this site because of the low traffic volumes, it was noted that east-west traffic was the most reluctant to change speed on the approach to the intersection.

There were 10 angle accidents reported during the four year period that this study encompassed. All but one of the accidents involved northbound vehicles. Road conditions played a large factor since only 4 accidents occurred on a dry street surface.

## IMPROVEMENTS

Since permanent sight restrictions exist in all corners of this intersection and there is sufficient evidence that it cannot function reasonably well as an uncontrolled intersection, vehicle right-of-way control is indicated. Yield signs cannot be used because yield signs require the same unobtrusive line of sight that is necessary for uncontrolled intersections. Therefore, stop sign control is recommended for the lesser volume, Fifth Avenue. There is no particular pattern of stop controlled intersections in this area and from observations, it appears that vehicles expect to slow or stop in the north and south directions.

Yellow curbs should be painted in the intersection area to reduce the possibility of vehicles parking too close to the intersection. Trees on the approach to the new stop sign installation should be trimmed to provide an unimpeded view of the stop signs. The city may also want to review the maintenance requirements in this area during inclement weather.

Long term improvements do not appear to be applicable to the conditions encountered at this site.

# STORY & FIFTH

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 250 |
| SOUTH APP | 150 |
| EAST APP | 500 |
| WEST APP | 500 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $410 |
| MDoT FUND | $260 |
| CITY FUND | $150 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 1.2 | 60% |
| PDO | 4.8 | 60% |

**BENEFIT/COST RATIO:** 87

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 67 | 5 |
| ACCIDENT RATE | 100 | 1 |
| SEVERITY | 53 | 6 |
| VOL/CAPACITY | 10 | 18 |
| SIGHT DIST. | 97 | 3 |
| DRIVER EXPECT | 63 | 13 |
| INFO DEFICIENT | 67 | 12 |
| HAZARD INDEX | 68.4 | 2 |
| B/C RATIO | 97 | 1 |

| | | |
|---|---|---|
| PRIORITY | 77.8 | 1 |

# SITE

# NUMBER

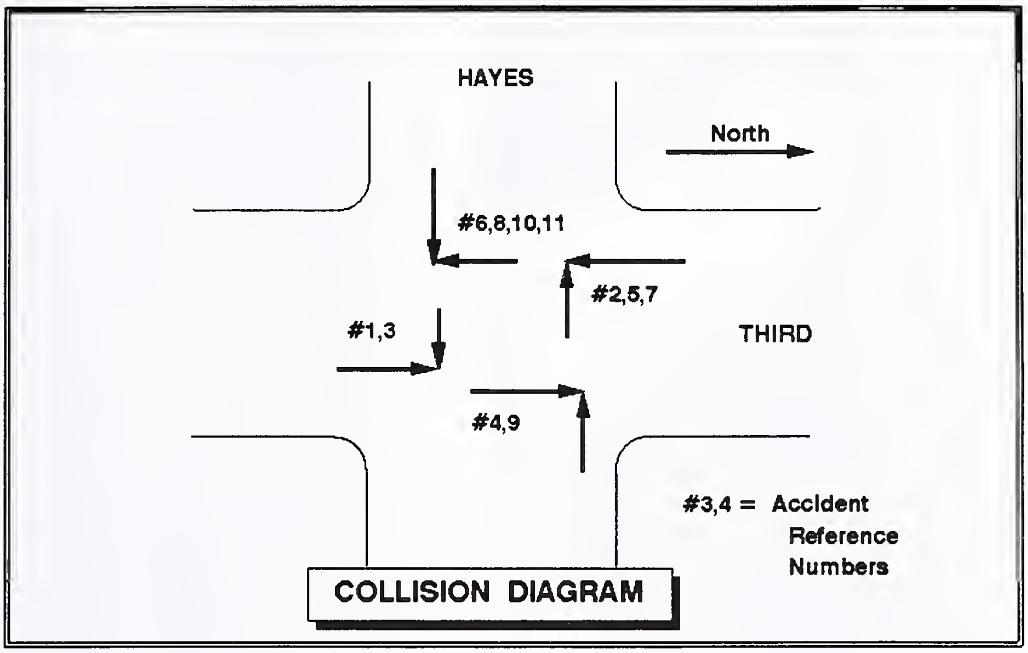
# 2

# HAYES

# and

# THIRD

# ACCIDENT SUMMARY
# HAYES & THIRD




| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| | | ACCIDENT KEY | | | | | | | |
| 1 | ANGLE | 5 | 11 | 88 | 1908 | INJURY | CLEAR | DRY | DAY |
| 2 | ANGLE | 10 | 25 | 88 | 2045 | PROP DAM | CLEAR | DRY | DAY |
| 3 | ANGLE | 10 | 31 | 88 | 1716 | PROP DAM | CLEAR | DRY | DAY |
| 4 | ANGLE | 11 | 3 | 88 | 1302 | PROP DAM | CLEAR | DRY | DAY |
| 5 | ANGLE | 4 | 13 | 89 | 1411 | INJURY | CLEAR | DRY | DAY |
| 6 | ANGLE | 11 | 29 | 89 | 1500 | PROP DAM | CLEAR | DRY | DAY |
| 7 | ANGLE | 8 | 14 | 90 | 1440 | PROP DAM | CLEAR | DRY | DAY |
| 8 | ANGLE | 10 | 1 | 90 | 1521 | INJURY | CLEAR | DRY | DAY |
| 9 | ANGLE | 10 | 23 | 90 | 800 | INJURY | CLEAR | DRY | DAY |
| 10 | ANGLE | 10 | 3 | 91 | 2000 | PROP DAM | CLEAR | DRY | NITE |
| 11 | ANGLE | 11 | 12 | 91 | 1410 | INJURY | RAIN | WET | DAY |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

## ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 4 | 1988 | #INJ ACC | 5 |
| 2 | 1989 | #FAT ACC | 0 |
| 3 | 1990 | #PDO ACC | 6 |
| 2 | 1991 | PERSON = | 6 * |
| 11 | TOTAL | NIGHTIME | 9% |

* No. of Persons Injured

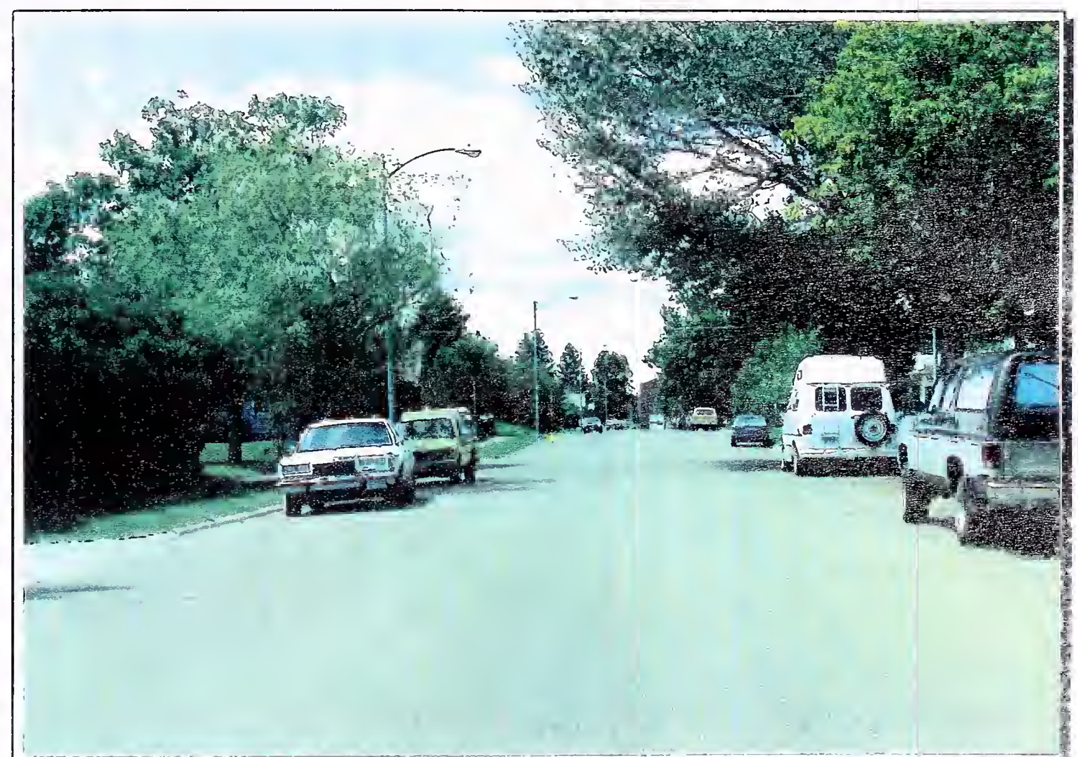
| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 11 | DRY | 91% |
| REAR END | 0 | WET | 9% |
| SIDESWIPE | 0 | SNOW | 0% |
| LEFT TRN | 0 | ICE | 0% |
| OTHER | 0 | OTHER | 0% |

Looking North

Looking South

THIRD

Looking East



Looking West

HAYES

## TRAFFIC OPERATIONS

Hayes Street is a local east-west street and Third Avenue is a local north-south street. Their intersection is in the middle of a residential area of Bozeman east of Montana State University. Problems and conditions typical of this area are discussed in the "Street Corridor" section of this report. Street widths are approximately 36 feet. Both streets have boulevards lined with large deciduous trees. Parking is allowed on both sides of the street. Traffic volumes on both streets are low.

A cluster of Pine trees on private property in the northeast corner of the intersection presents an obvious sight obstruction. Narrow street right-of-way and inadequate building setbacks at this intersection are typical of many Bozeman intersections. On-street parking appears to be light in the photos, but they were taken in the middle of summer. When the university in is full session, parking is very intense. The required sight distance for an uncontrolled intersection and 25 mph vehicle operating speeds is 110 feet. It was determined that a house in each corner of the west side of the intersection encroaches upon the sight triangle required for an uncontrolled intersection. It is also difficult to perceive the exact location of the intersection on all approaches because of parked cars and lack of other visual clues.

The intersection of Fourth Avenue and Hayes is only 150 feet to the west of this intersection, which is half the normal block in this area. The relative location of the two intersections can affect traffic flow and safety to some extent. Considering the low volumes encountered on these streets, the effect may be limited to visual perceptions and impaired judgement of vehicle speeds and gaps.

There were 10 angle accidents reported during the four year period that this study encompassed. The accidents involved all corners of the intersection. Eight of the eleven accidents occurred in October and November. The vast majority of accidents were on dry roads in clear weather.

## IMPROVEMENTS

Since permanent sight restrictions exist in two corners of this intersection and there is sufficient evidence that it cannot function reasonably well as an uncontrolled intersection, vehicle right-of-way control is indicated. Yield signs cannot be used because yield signs require the same unobtrusive line of sight that is necessary for uncontrolled intersections. Therefore, stop sign control is recommended. Normally, stop signs should be installed on the lower volume street. At this location, the City of Bozeman staff would prefer to see a pattern of stops every other block. Since the total volume of traffic entering and the relative difference in approach volumes is low, this request is considered feasible. Therefore, stop signs should be installed on Hayes. Trees on the approach to the new stop sign installation should be trimmed to provide an unimpeded view of the stop signs.

Yellow curbs should be painted in the intersection area to reduce the possibility of vehicles parking too close to the intersection. Since there is a heavy parking demand, the corner parking restrictions should also be signed and enforced. Parking setback distances are based on a dynamic vehicle model which would allow sufficient line of sight for a vehicle to cross Third from an initially stopped position.

Long term improvements at this location are dependant upon corridor improvements on the east side of Montana State University. No single improvement which would be considered a long term improvement could be made for this one intersection.

# HAYES & THIRD

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 300 |
| SOUTH APP | 300 |
| EAST APP | 500 |
| WEST APP | 500 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $760 |
| MDoT FUND | $660 |
| CITY FUND | $100 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 3.0 | 60% |
| PDO | 3.8 | 60% |

**BENEFIT/COST RATIO:** 65

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 69 | 3 |
| ACCIDENT RATE | 100 | 2 |
| SEVERITY | 56 | 5 |
| VOL/CAPACITY | 6 | 20 |
| SIGHT DIST. | 83 | 11 |
| DRIVER EXPECT | 67 | 12 |
| INFO DEFICIENT | 67 | 15 |
| HAZARD INDEX | 68.5 | 1 |
| B/C RATIO | 91 | 3 |

| | | |
|---|---|---|
| PRIORITY | 75.9 | 2 |

# SITE

# NUMBER

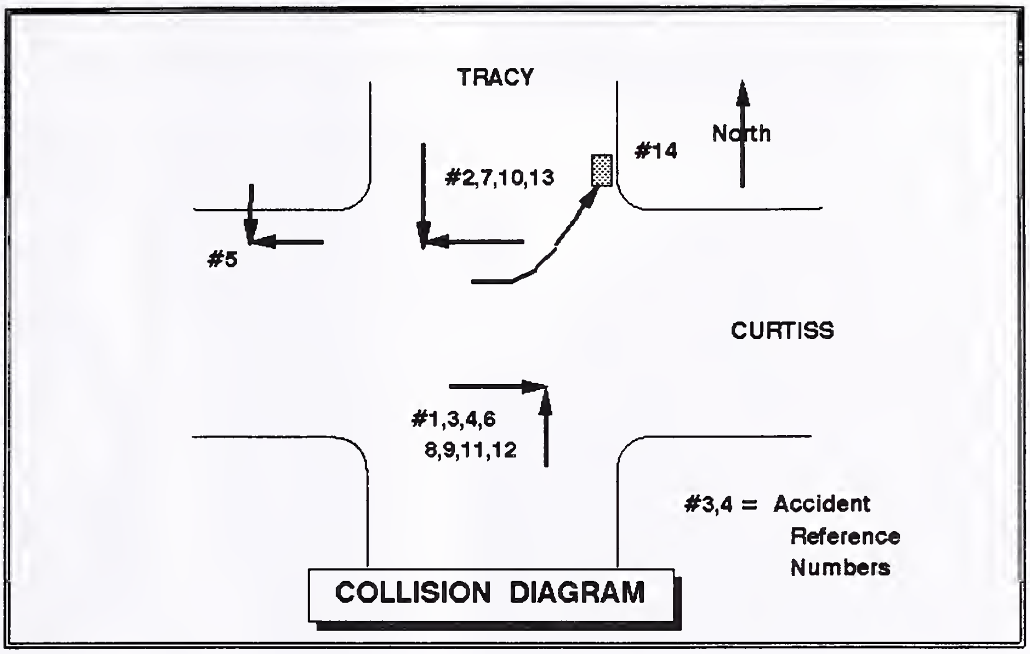
# 3

# CURTISS

# and

# TRACY

# ACCIDENT SUMMARY
# CURTISS & TRACY




| ACC NO. | ACCIDENT TYPE | ACCIDENT KEY MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ANGLE | 5 | 22 | 88 | 1736 | INJURY | CLEAR | DRY | DAY |
| 2 | ANGLE | 9 | 25 | 88 | 111 | INJURY | CLEAR | DRY | NITE |
| 3 | ANGLE | 11 | 14 | 88 | 750 | PROP DAM | SNOW | ICY | DAY |
| 4 | ANGLE | 1 | 20 | 89 | 1205 | INJURY | CLEAR | ICY | DAY |
| 5 | ANGLE | 2 | 6 | 89 | 1431 | PROP DAM | CLEAR | SNOW | DAY |
| 6 | ANGLE | 5 | 14 | 89 | 1102 | INJURY | CLEAR | DRY | DAY |
| 7 | ANGLE | 5 | 29 | 90 | 2035 | PROP DAM | CLEAR | WET | NITE |
| 8 | ANGLE | 9 | 24 | 90 | 1923 | PROP DAM | CLEAR | DRY | DAY |
| 9 | ANGLE | 11 | 2 | 90 | 829 | INJURY | CLEAR | ICY | DAY |
| 10 | ANGLE | 1 | 30 | 91 | 1404 | PROP DAM | CLEAR | ICY | DAY |
| 11 | ANGLE | 8 | 3 | 91 | 1650 | PROP DAM | CLEAR | DRY | DAY |
| 12 | ANGLE | 8 | 26 | 91 | 1102 | PROP DAM | CLEAR | DRY | DAY |
| 13 | ANGLE | 11 | 8 | 91 | 1158 | PROP DAM | CLEAR | DRY | DAY |
| 14 | PARKED CAR | 9 | 24 | 89 | 547 | INJURY | CLEAR | DRY | NITE |

## ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 3 | 1988 | #INJ ACC | 6 |
| 4 | 1989 | #FAT ACC | 0 |
| 3 | 1990 | #PDO ACC | 8 |
| 4 | 1991 | PERSON = | 10 * |
| 14 | TOTAL | NIGHTIME | 21% |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 13 | DRY | 57% |
| REAR END | 0 | WET | 7% |
| SIDESWIPE | 0 | SNOW | 7% |
| LEFT TRN | 0 | ICE | 29% |
| OTHER | 1 | OTHER | 0% |

Looking North

Looking South

TRACY

Looking East

Looking West

CURTISS

## TRAFFIC OPERATIONS

The intersection of Curtiss and Tracy are two local streets which intersect in an older residential area on the fringe of the Bozeman CBD. Curtiss is an east-west street and Tracy is a north-south street which parallels Willson Avenue, a major arterial. Because of congestion on Willson near the downtown intersections, southbound drivers tend to use Tracy Avenue in order to bypass the more congested intersections. Thus, Tracy has higher traffic volumes than would be considered representative of a local street.

Tracy Avenue is approximately 34 feet wide and has intense parking demand. Parking is prohibited on the east side of Tracy for one block south of the intersection. Both streets have boulevards lined with large deciduous trees. These trees typically have large trunks and low growing branches. Narrow street right-of-way and inadequate building setbacks at this intersection are typical of many Bozeman intersections. However, this intersection is more crowded than most. There are permanent sight obstructions in all corners due to houses and mounded landscaping. The required sight distance for an uncontrolled intersection and 25 mph vehicle operating speeds is 110 feet. It was determined that a house in each corner of the west side of the intersection encroaches upon the sight triangle required for an uncontrolled intersection. It is also difficult to perceive the exact location of the intersection on the approaches to this intersection because of parked cars and lack of other visual clues. The streets are so confining that drivers must devote a significant amount of their concentration on purely navigational tasks. It was observed that the majority of vehicles came to a near stop before entering the intersection. Obviously the minority of drivers who do not approach the intersection with this degree of caution are at risk.

There were 13 angle accidents reported during the four year study period and one parked car accident. The number of accidents were consistent for each year. There were a significant number of accidents on snowy or icy roads, but considering the amount of shade in this intersection, it is probable that ice stays in this area longer than at other locations.

## IMPROVEMENTS

Since permanent sight restrictions exist in all corners of this intersection and there is sufficient evidence that it cannot function reasonably well as an uncontrolled intersection, vehicle right-of-way control is indicated. Yield signs cannot be used because yield signs require the same unobtrusive line of sight that is necessary for uncontrolled intersections. Therefore, stop sign control is recommended for the lesser volume street, Curtiss Street. Stop signs are also present on adjoining intersections east and west. Trees on the approach to the new stop sign installation should be trimmed to provide an unimpeded view of the stop signs.

Yellow curbs should be painted in the intersection area to reduce the possibility of vehicles parking too close to the intersection. Since there is a heavy parking demand and the existing curbs are in poor condition, the corner parking restrictions should also be signed and enforced. Parking setback distances are based on a dynamic vehicle model which would allow sufficient line of sight for a vehicle to cross Tracy from an initially stopped position.

In addition to these improvements, it is recommended that stop bars, crosswalk markings and a short section of centerline be added to the Curtiss Street approaches. A significant amount of north-south pedestrian traffic occurs in this area. The crosswalk markings combined with stop bars and centerlines will reinforce the perception of a stop condition at this intersection

Long term improvements at this location cannot be foreseen.

# CURTISS & TRACY

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 1600 |
| SOUTH APP | 1600 |
| EAST APP | 800 |
| WEST APP | 900 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $1,340 |
| MDoT FUND | $1,240 |
| CITY FUND | $100 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 3.2 | 53% |
| PDO | 4.8 | 60% |

**BENEFIT/COST RATIO:** 54

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 76 | 1 |
| ACCIDENT RATE | 71 | 4 |
| SEVERITY | 62 | 3 |
| VOL/CAPACITY | 19 | 15 |
| SIGHT DIST. | 90 | 7 |
| DRIVER EXPECT | 71 | 7 |
| INFO DEFICIENT | 75 | 7 |
| HAZARD INDEX | 67.4 | 3 |
| B/C RATIO | 87 | 4 |

| | | |
|---|---|---|
| PRIORITY | 73.8 | 3 |

SITE

NUMBER

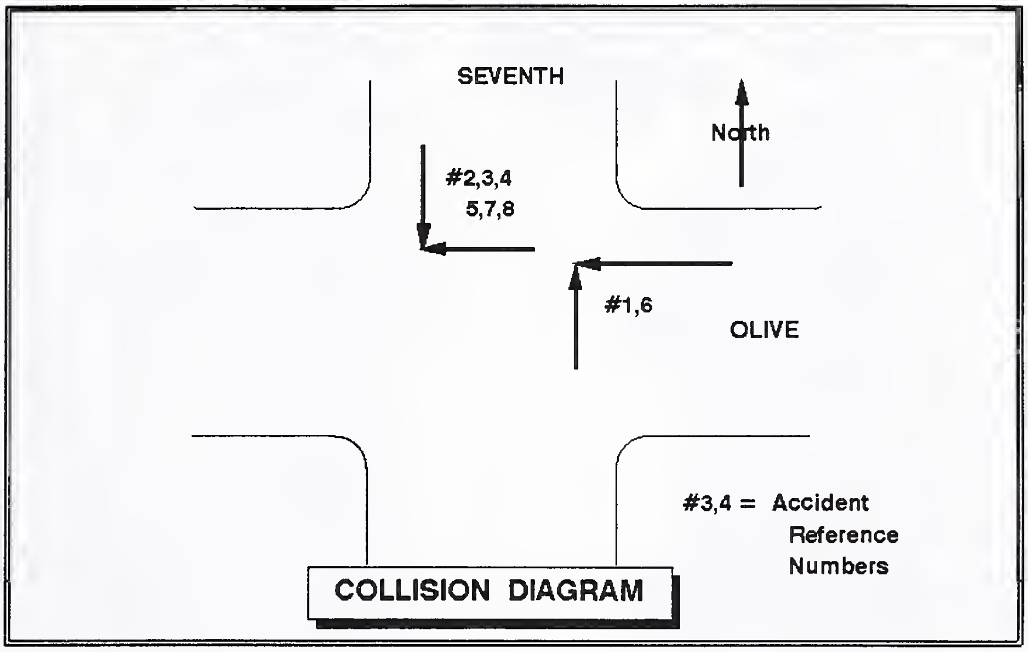
4

# OLIVE

# and

# SEVENTH

# ACCIDENT SUMMARY
# OLIVE & SEVENTH




| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| | | ACCIDENT KEY | | | | | | | |
| 1 | ANGLE | 1 | 4 | 88 | 1601 | PROP DAM | CLEAR | ICY | DAY |
| 2 | ANGLE | 10 | 3 | 88 | 935 | INJURY | CLEAR | DRY | DAY |
| 3 | ANGLE | 4 | 18 | 89 | 1633 | INJURY | CLEAR | DRY | DAY |
| 4 | ANGLE | 6 | 10 | 89 | 30 | PROP DAM | RAIN | WET | NITE |
| 5 | ANGLE | 8 | 2 | 89 | 1851 | INJURY | CLEAR | DRY | DAY |
| 6 | ANGLE | 12 | 10 | 89 | 1615 | PROP DAM | SNOW | SNOW | DAY |
| 7 | ANGLE | 6 | 28 | 91 | 1644 | PROP DAM | CLEAR | DRY | DAY |
| 8 | ANGLE | 9 | 17 | 91 | 1620 | INJURY | CLEAR | DRY | DAY |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

## ACCIDENT STATISTICS

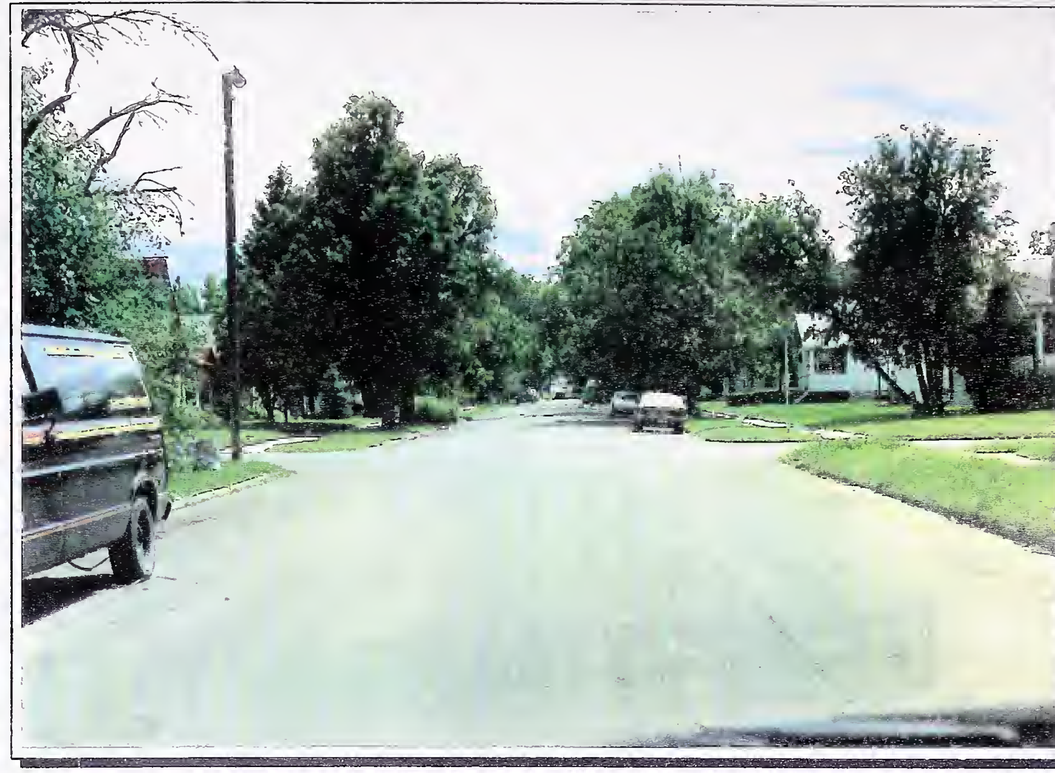
| NO. ACC. | YEAR | | |
|---|---|---|---|
| 2 | 1988 | #INJ ACC | 4 |
| 4 | 1989 | #FAT ACC | 0 |
| 0 | 1990 | #PDO ACC | 4 |
| 2 | 1991 | PERSON = | 5 * |
| 8 | TOTAL | NIGHTIME | 13% |

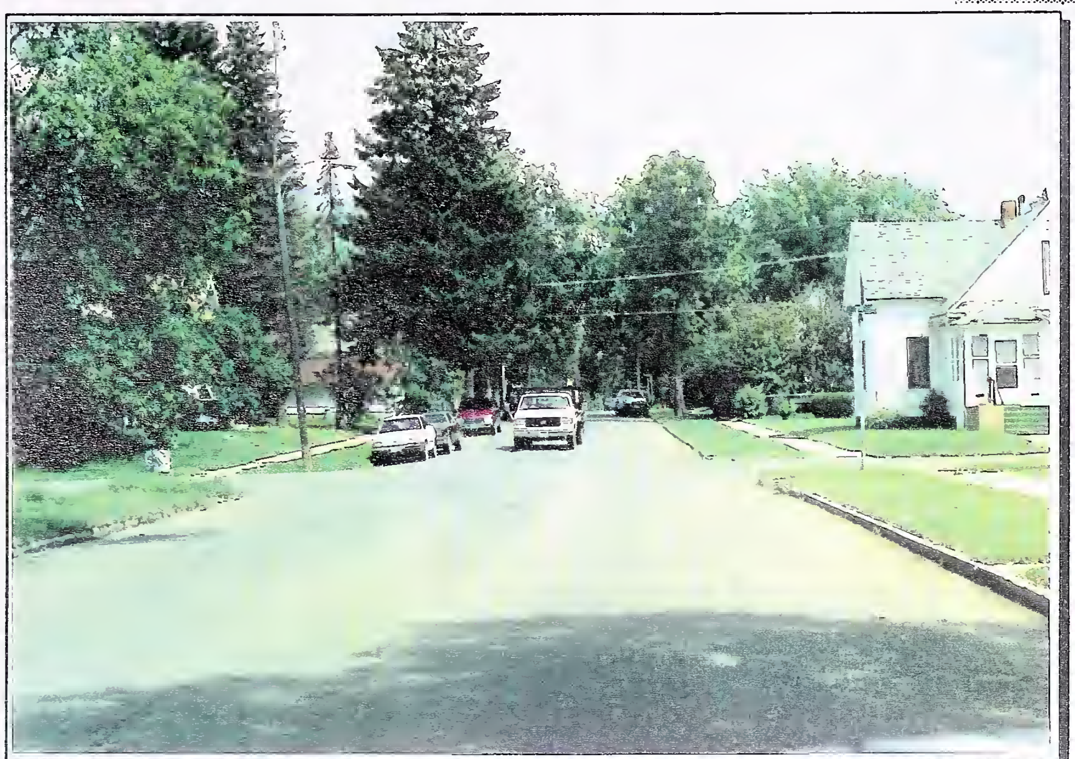
* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 8 | DRY | 63% |
| REAR END | 0 | WET | 13% |
| SIDESWIPE | 0 | SNOW | 13% |
| LEFT TRN | 0 | ICE | 13% |
| OTHER | 0 | OTHER | 0% |


Looking North

SEVENTH


Looking South


Looking East

OLIVE


Looking West

## TRAFFIC OPERATIONS

Olive and Seventh are two local streets which intersect in a residential area. Olive is an east-west street and Seventh Avenue is a north-south street which parallels S. 8th Avenue, a major arterial. The intersection is also located one block south of Babcock, a one-way eastbound arterial, and two blocks south of Main Street. Because of its location relative to these arterials and their operating requirements, this intersection carries a large amount of circulation traffic. This traffic is reflected in the predominant southbound right turn movements from Seventh.

Both streets are approximately 34 feet wide and parking demand is relatively light except near the intersection corners. Trees in the boulevard area are not as dense as at other intersections in this part of town. However, a tree on the east side of Seventh, north of the intersection has branches that actually rest on the street surface and impedes the line of vision. Narrow street right-of-way and inadequate building setbacks at this intersection are typical of many Bozeman intersections. There are permanent sight obstructions in all corners due to houses and mounded landscaping. The required sight distance for an uncontrolled intersection and 25 mph vehicle operating speeds is 110 feet. It was determined that a house in each corner of the intersection encroaches upon the sight triangle required for an uncontrolled intersection.

It was observed that the majority of east-west traffic proceeds through the intersection without slowing or even looking and southbound right turning vehicles barely slow to negotiate the turn. One of the reasons why westbound traffic is unlikely to proceed with caution thru this intersection is the fact that drivers are driving toward the major intersection ahead and their attention is focused past the intersection in question. Southbound right turn drivers are in the process of circling the block to gain access to N 8th or Main Street and do not expect to be delayed by conflicting traffic.

There were 8 angle accidents reported during the four year study period. Six of the eight accidents involved southbound and westbound vehicles which is consistent with the observed operations and conflicts. There were a significant number of accidents on less than ideal road surfaces. This was also a high severity location, with eight accidents producing 5 injuries.

Because the speeds on these streets are between 25 and 30 mph, the high incidence of injuries would indicate that little time was available for braking or avoidance maneuvers.

## IMPROVEMENTS

Since permanent sight restrictions exist in all corners of this intersection and there is sufficient evidence that it cannot function reasonably well as an uncontrolled intersection, vehicle right-of-way control is indicated. Yield signs cannot be used because yield signs require the same unobtrusive line of sight that is necessary for uncontrolled intersections. Therefore, stop sign control is recommended for the lesser volume street, Seventh Avenue. Stop signs are also present on Seventh and Babcock and at Olive and 8th. Trees on the approach to the new stop sign installation should be trimmed to provide an unimpeded view of the stop signs and the tree encroaching on the street surface should be trimmed to at least eight feet above the ground.

Yellow curbs should be painted in the intersection area to reduce the possibility of vehicles parking too close to the intersection. Also the yellow curbs will help drivers visual perception of the intersection location. Since sight distance is critical at this intersection, corner parking restrictions on Olive should also be signed and enforced. Parking setback distances are based on a dynamic vehicle model which would allow sufficient line of sight for a vehicle to cross Olive from a stopped position on Seventh.

During review of site recommendations with the City staff, significant discussions were devoted to this location. The staff felt that installation of stop signs on Seventh may be perceived as an action which would encourage thru traffic on Olive and Olive Street already has more traffic than desirable, for a local street. This concern was fostered by complaints registered against a similar situation when stop signs were installed by the City at Sixth and Olive, previously.

The apparent problem with higher traffic volumes on Olive street is directly related to the location of Babcock, one block north. Babcock is a way one-way, eastbound street which was designed to operate as part of a one-way couplet with Mendenhall (westbound). The only problem is, Main Street lies

between Babcock and Mendenhall. Since Main Street is congested and their are so few cross links between Babcock and Mendenhall, the couplet system does not serve circulation traffic very well. Olive Street picks up additional traffic from Babcock and acts as the other half of a one-way couplet. This is born out by the fact that westbound traffic on Olive is 5 times greater than eastbound traffic.

A suggested alternative to the recommended improvements was to install stop signs on Olive Street with the intent of discouraging thru traffic and reducing traffic volumes on Olive. This idea would have merit except for the following reasons:

1. The situation on Olive is a part of larger street system problem involving an inadequate one-way couplet system. No discernible effect would be realized by penalizing traffic on Olive at this intersection, especially since it is only one block east of South Eight, a major arterial. Even if stop signs were installed at every intersection on Olive, travel time for circulation traffic would still be less than having to enter or cross Main Street for westbound travel.

2. Experience has shown that installation of stop control on the major legs of an intersection degrades safety and makes drivers loose respect for stop signs. Drivers who routinely enter an intersection without seeing other vehicles on the side approach, become accustomed to not stopping at inappropriately placed stop signs. After a period of time, the stop signs actually become invisible to the conscious mind and accident potential increases.

3. It is estimated that the recommended improvements will decrease accidents at this site by 60 percent. If stop signs were placed on the Olive Street approaches instead, accident reduction is estimated to be only 20%. When statistical data is applied to this difference, the alternative involving stop signs on Olive would have approximately $5,200 per year less benefit than the recommended improvements.

4. Existing traffic observations indicate that east-west drivers on Olive do not acknowledge the presence of the side street intersection neither by slowing of their vehicles nor by head or eye movements. This is especially true of the higher volume westbound traffic. Since a stop controlled intersection with South Eight Avenue is only one block west, drivers' attention are focused on the intersection ahead instead of the intersection at hand. If a stop were installed on Olive, this factor would account for a high percentage of stop failures.

Because of the above noted reasons, it is not considered a reasonable alternative to install stop signs on Olive Street at this intersection. It is not possible to solve traffic volume problems on Olive by using conventional traffic control devices in unconventional ways. A long term solution to these problems must be based on transportation system improvements with a much broader scale, such as the Transportation Plan.

# OLIVE & SEVENTH

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 800 |
| SOUTH APP | 250 |
| EAST APP | 1400 |
| WEST APP | 1600 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $760 |
| MDoT FUND | $660 |
| CITY FUND | $100 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 2.4 | 60% |
| PDO | 2.4 | 60% |

**BENEFIT/COST RATIO:** 54

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 61 | 10 |
| ACCIDENT RATE | 54 | 7 |
| SEVERITY | 59 | 4 |
| VOL/CAPACITY | 42 | 5 |
| SIGHT DIST. | 68 | 18 |
| DRIVER EXPECT | 75 | 16 |
| INFO DEFICIENT | 67 | 16 |
| HAZARD INDEX | 60.5 | 6 |
| B/C RATIO | 86 | 5 |

| | | |
|---|---|---|
| PRIORITY | 68.9 | 4 |

# SITE

# NUMBER

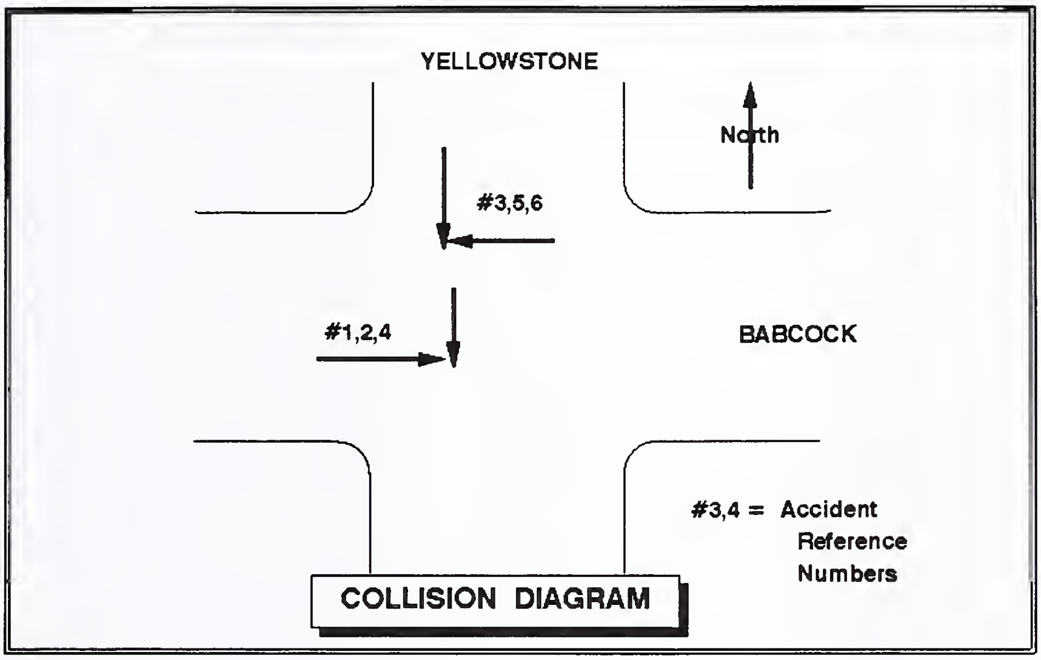
# 5

# BABCOCK

# and

# YELLOWSTONE

# ACCIDENT SUMMARY
## BABCOCK & YELLOWSTONE



COLLISION DIAGRAM

### ACCIDENT KEY

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ANGLE | 6 | 29 | 89 | 1650 | INJURY | CLEAR | DRY | DAY |
| 2 | ANGLE | 12 | 24 | 89 | 1150 | INJURY | CLEAR | ICY | DAY |
| 3 | ANGLE | 6 | 28 | 90 | 2029 | INJURY | CLEAR | DRY | DAY |
| 4 | ANGLE | 11 | 10 | 90 | 1418 | PROP DAM | CLEAR | DRY | DAY |
| 5 | ANGLE | 1 | 13 | 91 | 1706 | PROP DAM | RAIN | WET | NITE |
| 6 | ANGLE | 12 | 1 | 91 | 2047 | INJURY | CLEAR | ICY | NITE |
| | | | | | | | | | |
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### ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 0 | 1988 | #INJ ACC | 4 |
| 2 | 1989 | #FAT ACC | 0 |
| 2 | 1990 | #PDO ACC | 2 |
| 2 | 1991 | PERSON = | 8 * |
| 6 | TOTAL | NIGHTIME | 33% |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 6 | DRY | 50% |
| REAR END | 0 | WET | 17% |
| SIDESWIPE | 0 | SNOW | 0% |
| LEFT TRN | 0 | ICE | 33% |
| OTHER | 0 | OTHER | 0% |

Looking North

**YELLOWSTONE**

Looking South

Looking East From South Leg

**BABCOCK**

Looking West

## TRAFFIC OPERATIONS

Babcock, at the intersection location is near the western extremity of its current length. It is classified as an collector street. Babcock extends the length of Bozeman in an east-west direction, but it is not continuous. In this location, its western terminus is at Main Street. Yellowstone is a local north-south street serving a newer subdivision on the west end of Bozeman. At their intersection, both streets are approximately 40 feet wide. To the east of the intersection, Babcock narrows significantly to approximately 24' wide with no curb and gutter. There are no large trees within the intersection area and there is only one house, in the southwest corner. Empty lots in the other four corners tend to grow grass and weeds that get to be 36" to 40" tall. During the initial observation period, the grass severely limited sight distance. At a second observation period, the grass had been mowed in triangular patches on all corners.

Operational observations indicate that there is a predominant east to north traffic flow. Since most of the drivers are familiar with the area they tend to drive the intersection on auto pilot and come to expect certain movements from approaching traffic. During a one hour observation period, two near misses were noted which involved the southbound and westbound movements. In each case, the southbound driver saw the westbound vehicle but assumed it would turn right, as is the pattern. Similar, but not as dramatic, conflicts were observed for southbound and eastbound traffic.

The accidents were split between southbound-westbound and southbound-eastbound directions. Half of the accidents occurred on roads which were dry. A significant percentage of accidents were at night time.

## IMPROVEMENTS

No permanent sight restrictions exist in any of the corners of this intersection and no other type of sight obstruction are present during the majority of the time. Traffic volumes are relatively high for a local type intersection and turning movements indicate an unbalanced flow. This intersection cannot obviously function as an uncontrolled intersection because of the traffic

conditions at this site. Because Babcock is a collector type street and has the assumed free flow condition by drivers using it, it is recommended that stop control be implemented on the Yellowstone Avenue approaches. In order to reinforce the stop condition and provide positive guidance through the intersection, it is also recommended that centerline pavement markings be painted and stop bars added to the stop approaches. Parking restrictions at the corners should be marked by painting the curb yellow. This will also aid the driver in estimating time and distance to the intersection by highlighting the intersection location. One other recommendation, not related to the intersection, would be installation of a road narrows sign for eastbound traffic. The alignment of Babcock transitions sharply to the east and there are no markings or signs to indicate this transition. The city may also want to consider installing a few delineators in the transition area in the future.

Since this location has a high night time accident rate, lighting was an initial consideration. However, highly reflective stop signs should provide proper control during night time operations.

Long term improvements other than future lighting could not be considered feasible until traffic volumes increase significantly at this intersection planned developments should provide ample time to evaluate and plan other measures before they become necessary.

# BABCOCK & YELLOWSTONE

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 1700 |
| SOUTH APP | 600 |
| EAST APP | 1700 |
| WEST APP | 1100 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | YES |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $730 |
| MDoT FUND | $730 |
| CITY FUND | $0 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 2.0 | 50% |
| PDO | 1.0 | 50% |

**BENEFIT/COST RATIO:** 71

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 54 | 13 |
| ACCIDENT RATE | 36 | 12 |
| SEVERITY | 76 | 1 |
| VOL/CAPACITY | 24 | 13 |
| SIGHT DIST. | 30 | 20 |
| DRIVER EXPECT | 71 | 19 |
| INFO DEFICIENT | 50 | 19 |
| HAZARD INDEX | 51.8 | 15 |
| B/C RATIO | 93.2 | 2 |

| | | |
|---|---|---|
| PRIORITY | 65.4 | 5 |

# SITE

# NUMBER

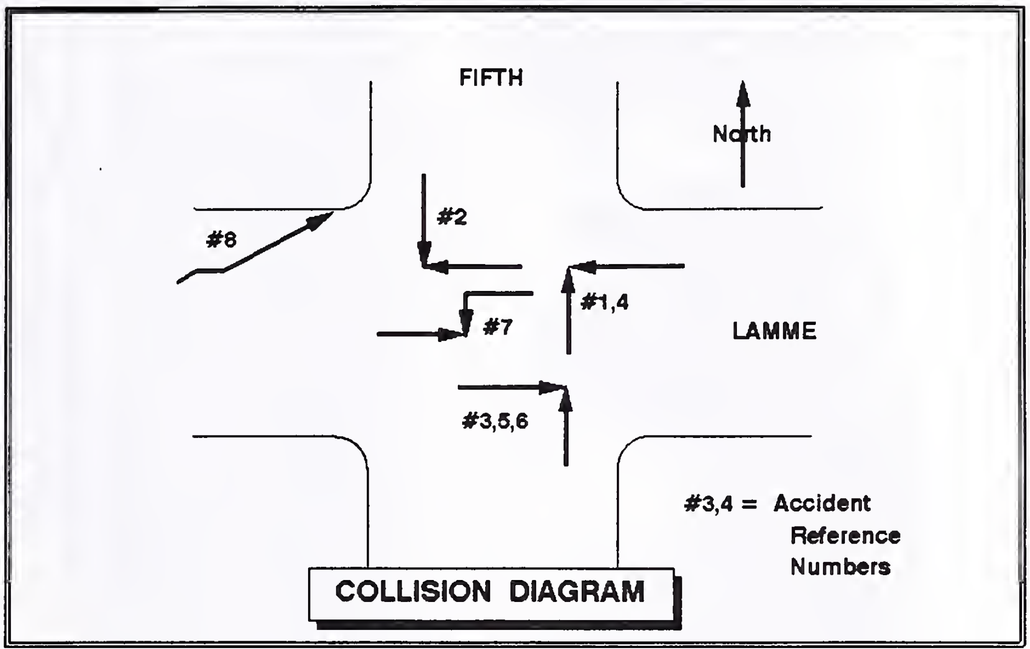
# 6

# LAMME

# and

# FIFTH

## ACCIDENT SUMMARY
## LAMME & FIFTH




| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| | | ACCIDENT KEY | | | | | | | |
| 1 | ANGLE | 6 | 25 | 89 | 1601 | INJURY | CLEAR | DRY | DAY |
| 2 | ANGLE | 7 | 2 | 89 | 1547 | PROP DAM | CLEAR | DRY | DAY |
| 3 | ANGLE | 4 | 30 | 90 | 1036 | INJURY | CLEAR | DRY | DAY |
| 4 | ANGLE | 5 | 8 | 90 | 1704 | PROP DAM | CLEAR | DRY | DAY |
| 5 | ANGLE | 11 | 2 | 91 | 1145 | PROP DAM | SNOW | ICY | DAY |
| 6 | ANGLE | 11 | 7 | 91 | 1258 | PROP DAM | CLEAR | DRY | DAY |
| 7 | LEFT TURN | 2 | 24 | 89 | 1451 | PROP DAM | CLEAR | DRY | DAY |
| 8 | SINGLE VEH | 9 | 12 | 89 | 2325 | INJURY | CLEAR | DRY | NITE |
| | | | | | | | | | |
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### ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 0 | 1988 | #INJ ACC | 3 |
| 4 | 1989 | #FAT ACC | 0 |
| 2 | 1990 | #PDO ACC | 5 |
| 2 | 1991 | PERSON = | 3 * |
| 8 | TOTAL | NIGHTIME | 13% |

*** No. of Persons Injured**

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 6 | DRY | 87% |
| REAR END | 0 | WET | 0% |
| SIDESWIPE | 0 | SNOW | 0% |
| LEFT TRN | 1 | ICE | 13% |
| OTHER | 1 | OTHER | 0% |

Looking North

Looking South

FIFTH

Looking East

Looking West

LAMME

## TRAFFIC OPERATIONS

Lamme Street is a local east -west street and its intersection with Fifth Avenue is one of four study intersections along the Fifth Avenue corridor north of Mendenhall. Specific conditions and problems in this area can be found in the "Street Corridor" section of this report. Lamme is 34 feet wide while Fifth is 40 feet wide north of the intersection and 30' wide south of the intersection. Because of its narrow width, parking is prohibited on the east side of the street south of the intersection.

The intersection is currently uncontrolled and carries relative high traffic volumes on the local streets. Approach traffic is approximately equal on all legs on the intersection. On-street parking in this area in moderate to heavy. There are trees and bushes within the area of influence of the intersection, but most of them are behind the boulevard. Hedges and trees provides sight obstructions that are obvious in the east half of the intersection. All of the corner buildings are well within the required sight triangle for an uncontrolled intersection and available sight distance is very restricted. Because of these conditions, the intersection operates like a four way stop intersection. The east-west movements appear to be the predominant non-stop movement.

There were 6 angle accidents; 1 left turn; and 1 single vehicle accident at this intersection during he reporting period. The angle accidents occurred in the corner which are not as sight restricted. This is probably due to the "misdirected attention syndrome", which occurs when an obvious sight obstruction exists and drivers concentrate on seeing around the obstruction while ignoring conflicts from the reverse direction. Most of the accidents occurred during clear weather; on dry streets; and in the daytime, either at noon or early afternoon.

## IMPROVEMENTS

Permanent sight restrictions exist in all corners of this intersection. Since uncontrolled and yield intersections require a sight triangle 110' on a side for traffic speeds up to 25 mph, this intersection warrants stop control.

Intersections on Fifth on either side of Lamme are currently stop controlled and since the existing east-west movements appear to be the predominant thru movement, stop signs should be installed on Fifth Avenue. No parking zones should also be modified to allowed adequate sight distance from the stopped position on Fifth. The restricted parking zone lengths were calculated using a dynamic vehicle model for the conditions existing at this site and are noted on the short term improvement sketch.

Long term improvements at this site would be dependent upon arterial road system improvements as discussed in the "street corridor" section of this report. It is not anticipated that traffic volumes will increase at this site or that any other control will be needed in the future.

# LAMME & FIFTH

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 1200 |
| SOUTH APP | 1400 |
| EAST APP | 1100 |
| WEST APP | 1300 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | YES |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $845 |
| MDoT FUND | $645 |
| CITY FUND | $200 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 1.2 | 40% |
| PDO | 2.5 | 50% |

**BENEFIT/COST RATIO:** 21

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 61 | 9 |
| ACCIDENT RATE | 46 | 9 |
| SEVERITY | 50 | 9 |
| VOL/CAPACITY | 27 | 11 |
| SIGHT DIST. | 90 | 6 |
| DRIVER EXPECT | 63 | 3 |
| INFO DEFICIENT | 83 | 3 |
| HAZARD INDEX | 57.5 | 10 |
| B/C RATIO | 66 | 7 |

| | | |
|---|---|---|
| PRIORITY | 60.3 | 6 |

# SITE

# NUMBER

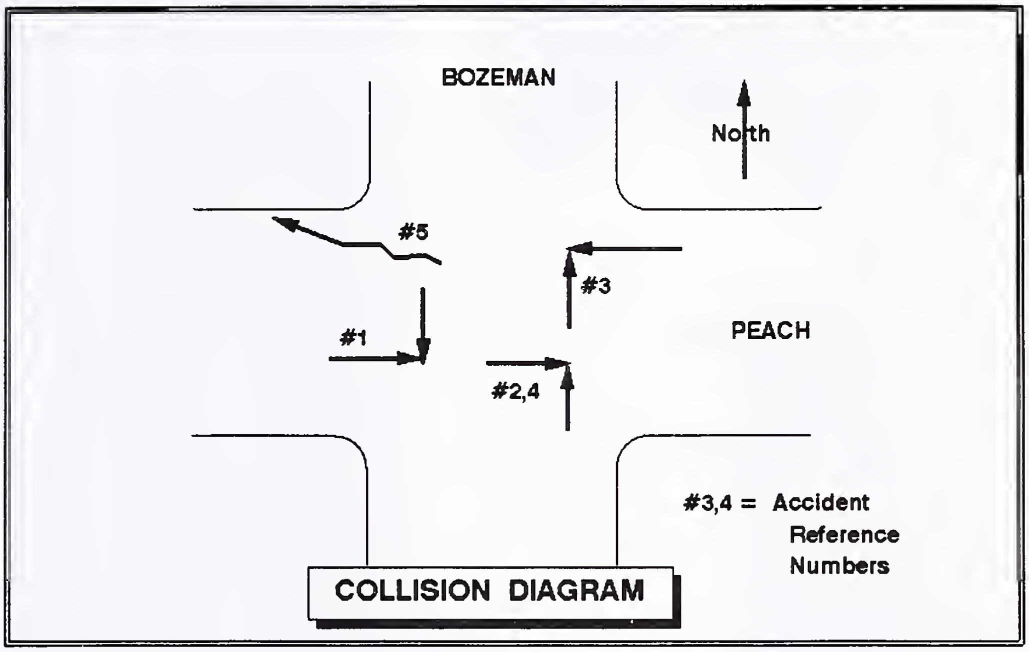
# 7

# PEACH

# and

# BOZEMAN

# ACCIDENT SUMMARY
# PEACH & BOZEMAN




**ACCIDENT KEY**

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ANGLE | 1 | 12 | 88 | 1505 | PROP DAM | CLEAR | ICY | DAY |
| 2 | ANGLE | 2 | 16 | 89 | 110 | INJURY | CLEAR | ICY | NITE |
| 3 | ANGLE | 3 | 7 | 91 | 940 | INJURY | CLEAR | DRY | DAY |
| 4 | ANGLE | 10 | 28 | 91 | 1921 | INJURY | CLEAR | ICY | NITE |
| 5 | SINGLE VEH | 1 | 24 | 88 | 51 | PROP DAM | CLEAR | ICY | NITE |
| | | | | | | | | | |
| | | | | | | | | | |
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| | | | | | | | | | |

**ACCIDENT STATISTICS**

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 2 | 1988 | #INJ ACC | 3 |
| 1 | 1989 | #FAT ACC | 0 |
| 0 | 1990 | #PDO ACC | 2 |
| 2 | 1991 | PERSON = | 5 * |
| 5 | TOTAL | NIGHTIME | 60% |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 4 | DRY | 20% |
| REAR END | 0 | WET | 0% |
| SIDESWIPE | 0 | SNOW | 0% |
| LEFT TRN | 0 | ICE | 80% |
| OTHER | 1 | OTHER | 0% |

**BOZEMAN**


Looking North


Looking South

**PEACH**

Looking East

Looking West

## TRAFFIC OPERATIONS

Peach Street is a two lane, east-west arterial street on the north end of Bozeman. Bozeman Avenue is a local north-south street. Stop control at this intersection is on Bozeman. Parking on Peach is light while parking on Bozeman is moderate to heavy. There are no pavement markings or other traffic control devices in this area. Traffic on Peach appears to have an upper range of pace speed above 35 mph while it is posted at 25 mph. A building in the southwest corner of this intersection is located just behind the sidewalk and obstructs line of sight from the northbound approach for a vehicle stopped at a normal position.

There were 4 angle accidents and one single vehicle accident at this intersection during the reporting period. All of the angle accidents involved drivers who did not see the stop signs. Sixty percent of the accidents occurred at night and 80% happened on icy streets.

## IMPROVEMENTS

Night visibility would appear to be a problem based on accident statistics. There is currently a light in the southeast corner, but the existing stop signs are not as reflective as they could be. The stop condition and intersection location should also be visually reinforced by marking stop bars and centerlines. It is recommended that the existing stop signs be replaced with 36"x36" signs and parking restrictions marked to avoid parked vehicles obstructing vision of the signs. No parking zones on Peach should be signed and marked according to the predominant vehicle dynamics existing at this intersection. The city should also review its winter maintenance program to determine if additional sanding should be initiated at this site.

Long term improvements at this site would be dependent upon future road improvements on Peach Street as traffic volumes increase.

# PEACH & BOZEMAN

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 700 |
| SOUTH APP | 700 |
| EAST APP | 4300 |
| WEST APP | 4600 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | |
| YIELD | |
| STOP | YES |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | YES |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $1,105 |
| MDoT FUND | $1,085 |
| CITY FUND | $20 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 1.8 | 60% |
| PDO | 0.8 | 30% |

**BENEFIT/COST RATIO:** 35

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 50 | 20 |
| ACCIDENT RATE | 17 | 18 |
| SEVERITY | 69 | 2 |
| VOL/CAPACITY | 41 | 7 |
| SIGHT DIST. | 86 | 10 |
| DRIVER EXPECT | 58 | 13 |
| INFO DEFICIENT | 67 | 13 |
| HAZARD INDEX | 51.1 | 16 |
| B/C RATIO | 77 | 6 |

| | | |
|---|---|---|
| PRIORITY | 59.7 | 7 |

SITE

NUMBER

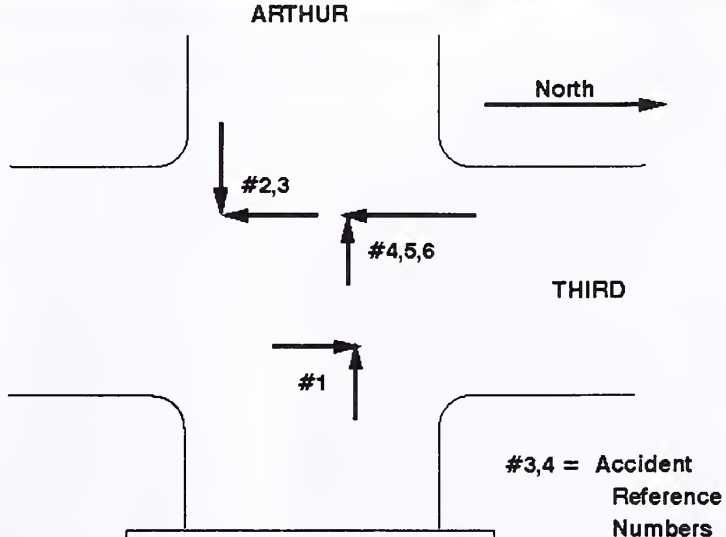
8

ARTHUR

and

THIRD

# ACCIDENT SUMMARY
# ARTHUR & THIRD




COLLISION DIAGRAM

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| | | ACCIDENT KEY | | | | | | | |
| 1 | ANGLE | 4 | 3 | 88 | 1236 | INJURY | CLEAR | DRY | DAY |
| 2 | ANGLE | 11 | 4 | 89 | 1510 | PROP DAM | CLEAR | DRY | DAY |
| 3 | ANGLE | 1 | 28 | 90 | 1718 | PROP DAM | CLEAR | ICY | NITE |
| 4 | ANGLE | 10 | 26 | 91 | 1657 | PROP DAM | RAIN | WET | DAY |
| 5 | ANGLE | 6 | 13 | 88 | 1654 | INJURY | CLEAR | DRY | DAY |
| 6 | ANGLE | 11 | 20 | 89 | 1500 | PROP DAM | CLEAR | DRY | DAY |
| | | | | | | | | | |
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## ACCIDENT STATISTICS

| NO. ACC. | YEAR | | | |
|---|---|---|---|---|
| 2 | 1988 | #INJ ACC | 2 | |
| 2 | 1989 | #FAT ACC | 0 | |
| 1 | 1990 | #PDO ACC | 4 | |
| 1 | 1991 | PERSON = | 2 | * |
| 6 | TOTAL | NIGHTIME | 17% | |

* No. of Persons Injured

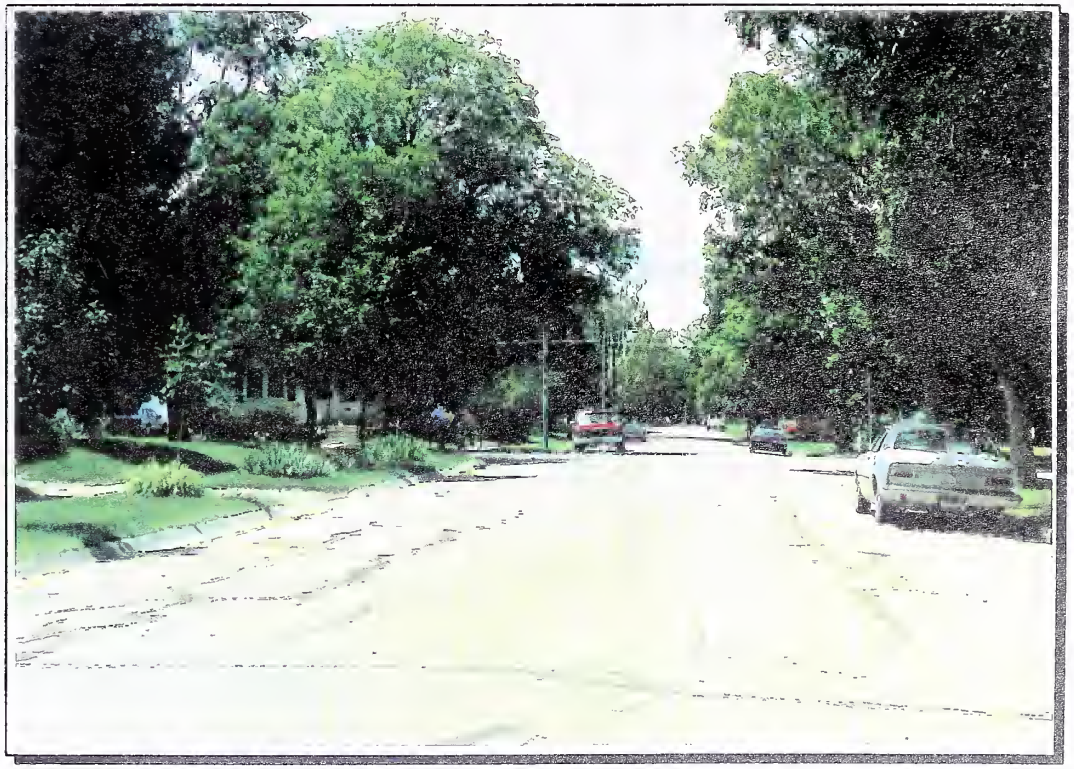
| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 6 | DRY | 67% |
| REAR END | 0 | WET | 17% |
| SIDESWIPE | 0 | SNOW | 0% |
| LEFT TRN | 0 | ICE | 17% |
| OTHER | 0 | OTHER | 0% |

Looking North

Looking South

THIRD

Looking East



Looking West

ARTHUR

## TRAFFIC OPERATIONS

Arthur Street is a local east-west and Third Avenue is a local north-south street. Their intersection is in the middle of a residential area of Bozeman east of Montana State University. Problems and conditions typical of this area are discussed in the "Street Corridor" section of this report. Street widths are approximately 32 feet. Both streets have boulevards lined with large deciduous trees. Parking is allowed on both sides of the street. Traffic volumes on both streets are relatively low. Both corners on the north side of the street have trees and hedges that are over grown and severely obstruct sight distance. It was observed that southbound vehicles slow to a near stop it see around trees.

Narrow street right-of-way and inadequate building setbacks at this intersection are typical of many Bozeman intersections. On-street parking appears to be light in the photos, but they were taken in the middle of summer. When the university in is full session, parking is very intense. The required sight distance for an uncontrolled intersection and 25 mph vehicle operating speeds is 110 feet. It was determined that houses in the southwest and northeast corners of the intersection encroaches upon the sight triangle required for an uncontrolled intersection. It is also difficult to perceive the exact location of the intersection on all approaches because of parked cars and lack of other visual clues.

The intersection of Fourth Avenue and Arthur is only 150 feet to the west of this intersection, which is half the normal block in this area. The relative location of the two intersections can affect traffic flow and safety to some extent. Considering the low volumes encountered on these streets, the effect may be limited to visual perceptions and impaired judgement of vehicle speeds and gaps.

There were 6 angle accidents reported during the four year period that this study encompassed. The accidents involved most corners of the intersection.

## IMPROVEMENTS

Since permanent sight restrictions exist in two corners of this intersection and there is sufficient evidence that it cannot function reasonably well as an uncontrolled intersection, vehicle right-of-way control is indicated. Yield signs cannot be used because yield signs require the same unobtrusive line of sight that is necessary for uncontrolled intersections. Therefore, stop sign control is recommended for the lesser volume, Arthur Street. The location of stop signs on Arthur would also be more visible than on Third because of site conditions. Trees on the approach to the new stop sign installations on Arthur should be trimmed to provide an unimpeded view of the stop signs.

Yellow curbs should be painted in the intersection area to reduce the possibility of vehicles parking too close to the intersection. Since there is a heavy parking demand, the corner parking restrictions should also be signed and enforced. Parking setback distances are based on a dynamic vehicle model which would allow sufficient line of sight for a vehicle to cross Third from an initially stopped position.

Long term improvements at this location are dependant upon corridor improvements on the east side of Montana State University. No single improvement which could be considered a long term improvement could be made for this one intersection.

# ARTHUR & THIRD

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 800 |
| SOUTH APP | 900 |
| EAST APP | 400 |
| WEST APP | 500 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $1,110 |
| MDoT FUND | $860 |
| CITY FUND | $250 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 1.2 | 60% |
| PDO | 2.4 | 60% |

**BENEFIT/COST RATIO:** 16

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 54 | 12 |
| ACCIDENT RATE | 61 | 5 |
| SEVERITY | 49 | 10 |
| VOL/CAPACITY | 14 | 16 |
| SIGHT DIST. | 90 | 8 |
| DRIVER EXPECT | 79 | 17 |
| INFO DEFICIENT | 67 | 17 |
| HAZARD INDEX | 59 | 7 |
| B/C RATIO | 60 | 8 |

| | | |
|---|---|---|
| PRIORITY | 59 | 8 |

# SITE

# NUMBER

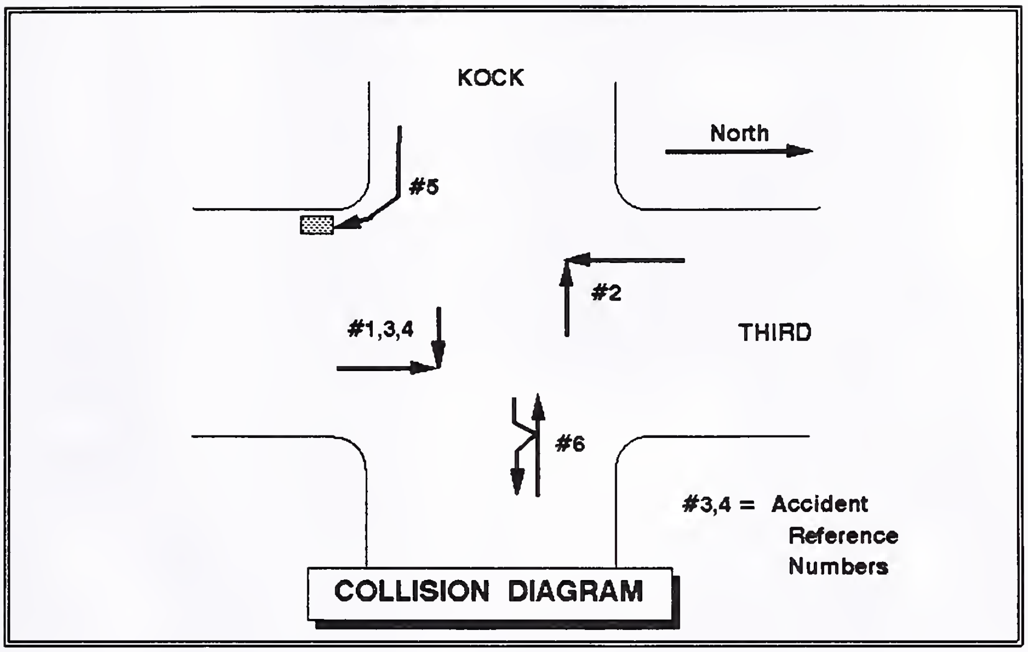
# 9

# KOCH

# and

# THIRD

## ACCIDENT SUMMARY
## KOCH & THIRD




COLLISION DIAGRAM

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| | | ACCIDENT KEY | | | | | | | |
| 1 | ANGLE | 1 | 4 | 88 | 1701 | PROP DAM | CLEAR | ICY | DAY |
| 2 | ANGLE | 12 | 1 | 88 | 1420 | PROP DAM | CLEAR | ICY | DAY |
| 3 | ANGLE | 10 | 31 | 90 | 1039 | INJURY | CLEAR | DRY | DAY |
| 4 | ANGLE | 8 | 30 | 91 | 900 | PROP DAM | CLEAR | DRY | DAY |
| 5 | PARKED CAR | 10 | 18 | 90 | 45 | PROP DAM | CLEAR | DRY | NITE |
| 6 | SIDESWIPE | 2 | 27 | 89 | 1204 | PROP DAM | SNOW | ICY | DAY |
| | | | | | | | | | |
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| | | | | | | | | | |

### ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 2 | 1988 | #INJ ACC | 1 |
| 1 | 1989 | #FAT ACC | 0 |
| 2 | 1990 | #PDO ACC | 5 |
| 1 | 1991 | PERSON = | 1 * |
| 6 | TOTAL | NIGHTIME | 17% |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 4 | DRY | 50% |
| REAR END | 0 | WET | 0% |
| SIDESWIPE | 1 | SNOW | 0% |
| LEFT TRN | 0 | ICE | 50% |
| OTHER | 1 | OTHER | 0% |

Looking North

THIRD

Looking South

Looking East

KOCH

Looking West

## TRAFFIC OPERATIONS

Koch Street is a local east-west and Third Avenue is a local north-south street. Their intersection is in the middle of a residential area of Bozeman south of Montana State University. Street widths are approximately 36 feet except for Koch on the west side of the intersection where the street is only 30 feet wide. Both streets have boulevards lined with large deciduous and evergreen trees. Parking is allowed on both sides of the street except for the narrow section of Koch, where parking is not allowed on the south side of the street. Traffic volumes on both streets are relatively low. Trunks of large trees along the streets are massive and imposing. On-street parking along both streets is moderate to heavy.

Narrow street right-of-way and inadequate building setbacks at this intersection are typical of many Bozeman intersections. The required sight distance for an uncontrolled intersection and 25 mph vehicle operating speeds is 110 feet. It was determined that buildings in all but the northwest corner are well within the sight triangle required for an uncontrolled intersection.

The intersection of Fourth Avenue and Koch is only 150 feet to the west of this intersection, which is half the length of a normal block in this area. The relative location of the two intersections can affect traffic flow and safety to some extent. Considering the low volumes encountered on these streets, the effect may be limited to visual perceptions and impaired judgement of vehicle speeds and gaps.

There were 4 angle, 1 sideswipe and 1 parked car accident reported during the four year period that this study encompassed. Fifty percent of the accidents occurred on icy streets.

## IMPROVEMENTS

Since permanent sight restrictions exist in three corners of this intersection and accident problems suggest that it cannot function reasonably well as an uncontrolled intersection, vehicle right-of-way control is indicated. Yield signs cannot be used because yield signs require the same unobtrusive line of sight that is necessary for uncontrolled intersections. Therefore, stop sign control is

recommended for the lesser volume, Koch Street. The location of stop signs on Koch would also be more visible than on Third because of site conditions and the existing tendency is for drivers on Koch to slow or stop while Third street traffic tends to be a thru movement.

Yellow curbs should be painted in the intersection area to reduce the possibility of vehicles parking too close to the intersection. Since there is a heavy parking demand, the corner parking restrictions should also be signed and enforced. Parking setback distances are based on a dynamic vehicle model which would allow sufficient line of sight for a vehicle to cross Third from an initially stopped position. A no parking sign should also be installed on the westbound approach because of vehicles observed parking at the corner.

Long term improvements at this location are not indicated by street function or growth tendencies.

# KOCH & THIRD

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 500 |
| SOUTH APP | 500 |
| EAST APP | 400 |
| WEST APP | 300 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $775 |
| MDoT FUND | $775 |
| CITY FUND | $0 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 0.8 | 60% |
| PDO | 2.0 | 40% |

**BENEFIT/COST RATIO:** 13

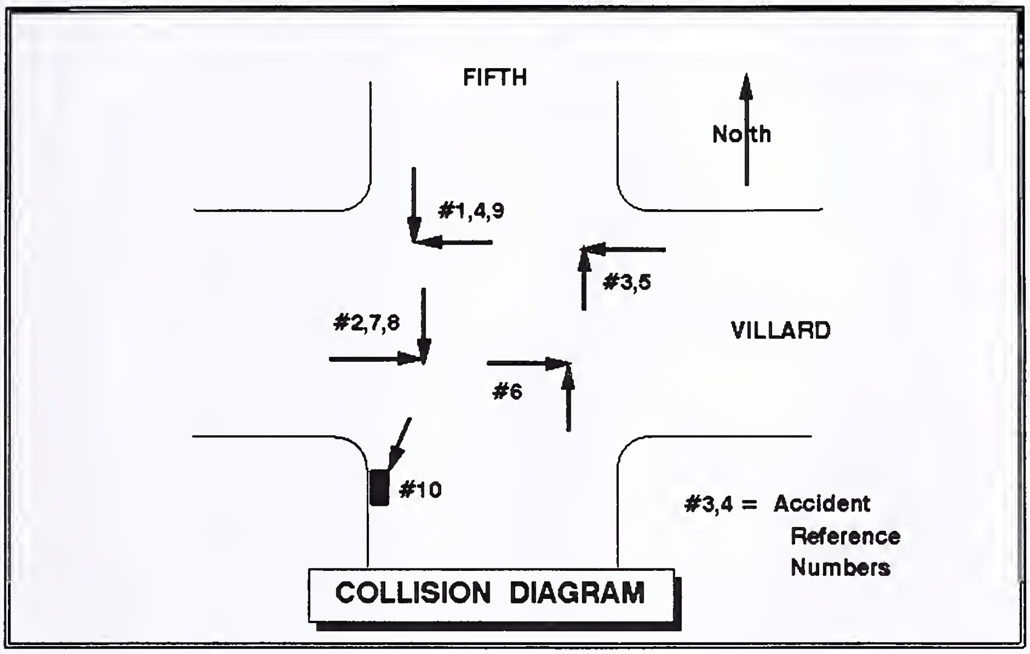
| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 54 | 14 |
| ACCIDENT RATE | 82 | 3 |
| SEVERITY | 43 | 14 |
| VOL/CAPACITY | 9 | 19 |
| SIGHT DIST. | 78 | 13 |
| DRIVER EXPECT | 63 | 18 |
| INFO DEFICIENT | 58 | 18 |
| HAZARD INDEX | 57.8 | 8 |
| B/C RATIO | 55 | 9 |

| | | |
|---|---|---|
| PRIORITY | 56.9 | 9 |

# SITE NUMBER 10

# VILLARD and FIFTH

# ACCIDENT SUMMARY
# VILLARD & FIFTH




COLLISION DIAGRAM

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ANGLE | 6 | 21 | 88 | 1615 | PROP DAM | CLEAR | DRY | DAY |
| 2 | ANGLE | 3 | 29 | 89 | 806 | INJURY | CLEAR | DRY | DAY |
| 3 | ANGLE | 5 | 11 | 89 | 1547 | PROP DAM | CLEAR | DRY | DAY |
| 4 | ANGLE | 2 | 13 | 90 | 1537 | PROP DAM | CLEAR | ICY | DAY |
| 5 | ANGLE | 4 | 5 | 90 | 1326 | PROP DAM | CLEAR | DRY | DAY |
| 6 | ANGLE | 9 | 28 | 90 | 1742 | PROP DAM | CLEAR | DRY | DAY |
| 7 | ANGLE | 1 | 5 | 91 | 1028 | PROP DAM | CLEAR | ICY | DAY |
| 8 | ANGLE | 1 | 18 | 91 | 845 | PROP DAM | CLEAR | ICY | DAY |
| 9 | ANGLE | 3 | 5 | 91 | 1723 | PROP DAM | CLEAR | WET | DAY |
| 10 | PARKED VEH | 10 | 29 | 91 | 1430 | PROP DAM | SNOW | SNOW | DAY |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

ACCIDENT KEY

## ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 1 | 1988 | #INJ ACC | 1 |
| 2 | 1989 | #FAT ACC | 0 |
| 3 | 1990 | #PDO ACC | 9 |
| 4 | 1991 | PERSON = | 1 * |
| 10 | TOTAL | NIGHTIME | 0% |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 9 | DRY | 50% |
| REAR END | 0 | WET | 10% |
| SIDESWIPE | 0 | SNOW | 10% |
| LEFT TRN | 0 | ICE | 30% |
| OTHER | 1 | OTHER | 0% |


Looking North

FIFTH

Looking South

Looking East

VILLARD

Looking West

## TRAFFIC OPERATIONS

Villard Street is a local east-west street and its intersection with Fifth Avenue is one of four study intersections along the Fifth Avenue corridor north of Mendenhall. Specific conditions and problems in this area can be found in the "Street Corridor" section of this report. Both Lamme and Villard are 36 feet wide. Parking in this area is light to moderate, but as is often the case, it is heaviest at the intersection corners.

The intersection is currently uncontrolled and carries relative high traffic volumes for local streets. Approach traffic is approximately equal on all legs on the intersection. Since this is a newer section of town, trees in the boulevard area are not as imposing as at other locations. However, there are pines tress in the northeast corner of the intersection that obstruct sight distance. Also, a high landscaped mound in the southeast corner present an obvious sight restriction that many drivers notice and adjust their speed and path to see past it. All of the corner buildings are within the required sight triangle for an uncontrolled intersection and available sight distance is very restrictive.

There were 9 angle accidents and 1 parked car accident at this intersection during he reporting period. The angle accidents occurred in all corners of the intersection. Only 50% of the accidents occurred on dry roads, but all of them were during daylight hours. Accidents have been increasing by 1 per year.

## IMPROVEMENTS

Permanent sight restrictions exist in all corners of this intersection. Since uncontrolled and yield intersections require a sight triangle 110' on a side for traffic speeds up to 25 mph, this intersection warrants stop control.

The intersection of Fifth and Beall south of the site is currently stop controlled and since the existing east-west movements appear to be the predominant thru movement, stop signs should be installed on Fifth Avenue. No parking zones should also be marked and signed to allowed adequate sight distance

from the stopped position on Fifth. The restricted parking zone lengths were calculated using a dynamic vehicle model for the conditions existing at this site and are noted on the short term improvement sketch.

Long term improvements at this site would be dependent upon arterial road system improvements as discussed in the "street corridor" section of this report. It is not anticipated that traffic volumes will increase at this site or that any other control will be needed in the future.

# VILLARD & FIFTH

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 900 |
| SOUTH APP | 1400 |
| EAST APP | 1000 |
| WEST APP | 1200 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | YES |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $1,100 |
| MDoT FUND | $1,100 |
| CITY FUND | $0 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 0.8 | 60% |
| PDO | 5.0 | 56% |

**BENEFIT/COST RATIO:** 12

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 67 | 6 |
| ACCIDENT RATE | 59 | 6 |
| SEVERITY | 40 | 19 |
| VOL/CAPACITY | 25 | 12 |
| SIGHT DIST. | 72 | 15 |
| DRIVER EXPECT | 63 | 10 |
| INFO DEFICIENT | 75 | 10 |
| HAZARD INDEX | 57.1 | 11 |
| B/C RATIO | 54 | 10 |

| | | |
|---|---|---|
| PRIORITY | 56.1 | 10 |

# SITE

# NUMBER

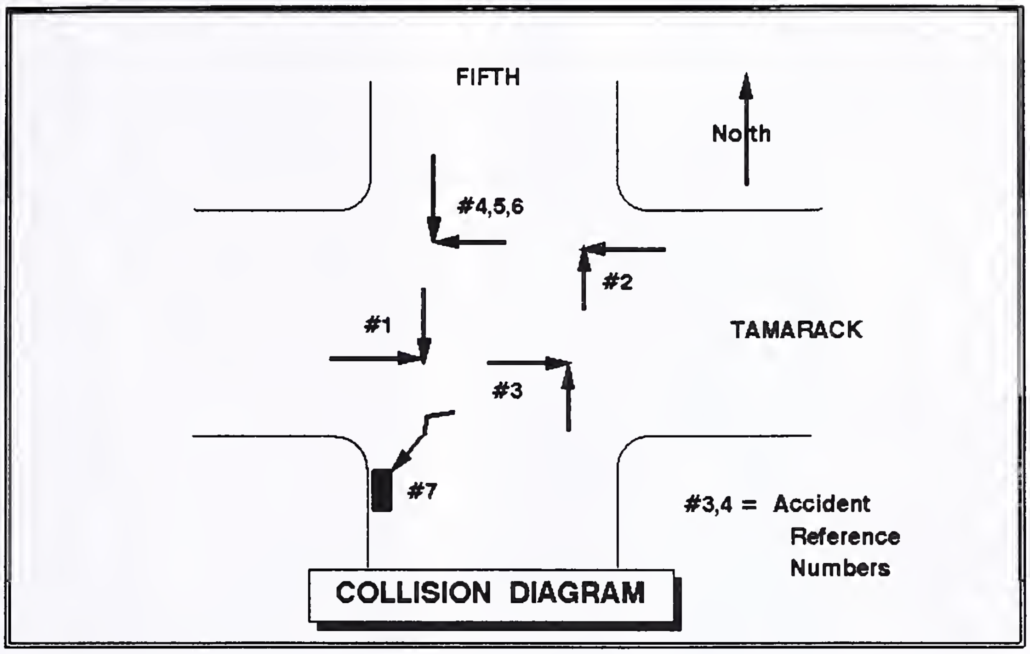
# 11

# TAMARACK

# and

# FIFTH

# ACCIDENT SUMMARY
# TAMARACK & FIFTH




**ACCIDENT KEY**

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ANGLE | 11 | 14 | 88 | 1746 | PROP DAM | SNOW | ICY | DAY |
| 2 | ANGLE | 11 | 16 | 89 | 1213 | PROP DAM | CLEAR | DRY | DAY |
| 3 | ANGLE | 12 | 16 | 89 | 1639 | INJURY | CLEAR | ICY | DAY |
| 4 | ANGLE | 7 | 17 | 90 | 1903 | INJURY | CLEAR | DRY | DAY |
| 5 | ANGLE | 10 | 9 | 91 | 828 | PROP DAM | CLEAR | DRY | DAY |
| 6 | ANGLE | 12 | 7 | 91 | 1710 | INJURY | CLEAR | WET | NITE |
| 7 | PARKED CAR | 11 | 27 | 91 | 1240 | PROP DAM | SNOW | SNOW | DAY |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

**ACCIDENT STATISTICS**

| NO. ACC. | YEAR | | | |
|---|---|---|---|---|
| 1 | 1988 | #INJ ACC | 3 | |
| 2 | 1989 | #FAT ACC | 0 | |
| 1 | 1990 | #PDO ACC | 4 | |
| 3 | 1991 | PERSON = | 3 | * |
| 7 | TOTAL | NIGHTIME | 14% | |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 6 | DRY | 43% |
| REAR END | 0 | WET | 14% |
| SIDESWIPE | 0 | SNOW | 14% |
| LEFT TRN | 0 | ICE | 29% |
| OTHER | 1 | OTHER | 0% |

Looking North

Looking South

FIFTH

Looking East

Looking West

TAMARACK

## TRAFFIC OPERATIONS

Tamarack is an east-west collector street and Fifth Avenue is a local North-south street. This intersection is one of four intersections on Fifth Avenue identified as a corridor problem area and discussed in the "Street Corridors" section of this report. Tamarack is the first east-west thru street south of Interstate 90 which has an intersection with 7th Avenue, a major north-south arterial.

Portions of this intersection are rural in nature since curb & gutter only exists on the eastbound Tamarack approach. A paved sidewalk/bike path extends up Tamarack and Fifth in the southeast corner of the intersection. This path continues north on Fifth by means of a widened pavement section separated from vehicular traffic by a wide double, solid white line. Parking controls include signs prohibiting parking on both sides of Fifth north of the intersection and on the north side of Tamarack east of the intersection. The intersection operates with stop control on the Fifth Avenue approaches. There are no pavement markings at this intersection.

The intersection area is fairly wide open with the exception of the southwest corner which has mobile homes parked as close as 15 feet from the edge of the road. Vehicles parked in front of the mobile homes on the west side of the intersection also park to the corner of the intersection. This situation presents very severe sight obstructions for northbound traffic.

A wide curb approach onto Tamarack from the back lot of the IGA store is located at the beginning of the curb radius in the northwest corner of the intersection. Vehicles using that approach effectively block sight distance for southbound Fifth Avenue traffic. In addition, this approach draws a significant amount of traffic (approximately 3% of all entering traffic). Westbound approach traffic use their turn signals for the right turn into the IGA lot while southbound traffic stopped at the intersection believe that these vehicles are going to turn right at Fifth. Southbound traffic proceeds into the intersection in front of the access traffic. Also, vehicles exiting the approach proceed diagonally thru the intersection and make other seemingly errant maneuvers.

Traffic volumes at this intersection are very high with a high percentage of turning movements. Pedestrian volumes were very low during traffic counts taken in mid-summer.

There were six angle accidents and one left turn accident during the reporting period. The accident rate of 0.53 accidents per million entering vehicles cannot be considered high and is even remarkable considering the potential conflicts at this intersection. The most predominant angle accident involved southbound and westbound vehicles. These accidents may be explained by the fact that a parking sign is in direct line with the stop sign for the southbound approach. Also, the IGA approach may be a factor involving drivers that focus their attention on the conflict resulting from the "fifth leg" approach.

## IMPROVEMENTS

Because of the high traffic volumes at this intersection, a traffic signal warrant was completed and can be found at the end of this site section. It was found that minor street approach traffic is only 50% and major street traffic is 83% of minimum volume warrants. None of the 10 signal warrants are any closer than this.

The primary improvement recommended at this intersection would be the elimination of the back lot approach to the IGA store. There is no justifiable reason for the location of this approach since truck traffic has ample room to maneuver within the lot and if not, a separate approach on Fifth Avenue could be used. If the City of Bozeman does not currently have an ordinance enabling closures of dangerous approaches, it is recommended that such an ordinance be established. The City should work with landowners to reestablish such approaches. Considering the public costs associated with hazardous approaches, compensatory payment to property owners for such changes should not even be considered under ordinary circumstances.

Visibility of the stop signs could be improved significantly if the existing signs were replaced with 36"x36" signs, located at a point where other signs and

topography does not interfere. No parking signs must also be installed along Tamarack at a location determined by dynamic vehicle modeling of the sight distanced required to cross Tamarack from the stopped position.

Considering the high traffic volumes, complete roadway pavement markings, including stop bars, crosswalks and centerlines should be installed. Signing and marking of the sidewalk/bike path through the intersection is critical considering that the facility was obviously built to cross Tamarack.

Long term improvements at this site will undoubtedly require a traffic signal and curbed street sections as this area becomes more urbanized and traffic volumes increase.

# TAMARACK & FIFTH

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 2500 |
| SOUTH APP | 2600 |
| EAST APP | 7200 |
| WEST APP | 6400 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | |
| YIELD | |
| STOP | YES |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | YES |
| WARNING | YES |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $3,530 |
| MDoT FUND | $2,215 |
| CITY FUND | $1,315 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 1.8 | 60% |
| PDO | 2.0 | 50% |

**BENEFIT/COST RATIO:** 7

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 58 | 11 |
| ACCIDENT RATE | 14 | 20 |
| SEVERITY | 52 | 7 |
| VOL/CAPACITY | 100 | 1 |
| SIGHT DIST. | 92 | 5 |
| DRIVER EXPECT | 75 | 4 |
| INFO DEFICIENT | 79 | 5 |
| HAZARD INDEX | 57.7 | 9 |
| B/C RATIO | 43 | 12 |

| | | |
|---|---|---|
| PRIORITY | 52.9 | 11 |

# TRAFFIC SIGNAL WARRANT ANALYSIS
## YEAR 1992
## TAMARACK & FIFTH

| WARRANT #1 - MINIMUM VEHICULAR VOLUME | | | | | |
|---|---|---|---|---|---|
| 70% WARRANT | | REQUIRED | | EXISTS | |
| YES | NO | MAJOR | MINOR | MAJOR | MINOR |
| 8TH HIGHEST HOUR | | 500 | 150 | 417 | 75 |
| % OF WARRANT MET | | | | 83% | 50% |

| WARRANT #2 - INTERRUPTION OF CONTINOUS TRAFFIC | | | | | |
|---|---|---|---|---|---|
| 70% WARRANT | | REQUIRED | | EXISTS | |
| YES | NO | MAJOR | MINOR | MAJOR | MINOR |
| 8TH HIGHEST HOUR | | 750 | 75 | 417 | 75 |
| % OF WARRANT MET | | | | 56% | 100% |

| WARRANT #3 - MINIMUM PEDESTRIAN TRAFFIC | | | | | |
|---|---|---|---|---|---|
| 50% WARRANT | | REQUIRED | | EXISTS | |
| YES | NO | PEDS | GAPS | PEDS | GAPS |
| FOUR HOURS | | 100 | 60 | NA | NA |
| PEAK HOUR | | 190 | 60 | NA | NA |
| % OF WARRANT MET | | | | 0% | ERR |

| WARRANT #4 - SCHOOL CROSSING [STUD | YES | NO |
|---|---|---|

| WARRANT #5 - PROGRESSIVE MOVEMENT | YES | NO |
|---|---|---|

| WARRANT #6 - ACCIDENT EXPERIENCE | YES | NO |
|---|---|---|

| WARRANT #7 - SYSTEMS WARRANT | YES | NO |
|---|---|---|

PAGE 1 of 2

| WARRANT #8 - COMBINATION OF WARRANTS | | | | |
|---|---|---|---|---|
| 80 % OF | REQUIRED | | EXISTS | |
| WARRANTS #1 & #2 | MAJOR | MINOR | MAJOR | MINOR |
| WARRANT #1 | 400 | 120 | 417 | 75 |
| WARRANT #2 | 600 | 60 | 417 | 75 |
| % OF WARRANT MET | | | 70% | 63% |

| WARRANT #9 - FOUR HOUR VOLUMES | | | | |
|---|---|---|---|---|
| | MAJOR | MINOR | CURVE NO. | WARRAN |
| 4TH HIGHEST HOUR | 510 | 90 | FIGURE | YES |
| NUMBER OF LANES | 1 | 1 | 4.7 | NO |

| WARRANT #10 - PEAK HOUR DELAY | | | | |
|---|---|---|---|---|
| PEAK HOUR: | MINOR LEG | | TOTAL ENTERING | |
| | DELAY | VOLUME | 4 LEGS | 3 LEGS |
| REQUIRED VALUES | 4 | 100 | 800 | 650 |
| EXISTING VALUES | 3 | 125 | 930 | |

| WARRANT #11 - PEAK HOUR VOLUME | | | | |
|---|---|---|---|---|
| | MAJOR | MINOR | CURVE NO. | WARRAN |
| PEAK HOUR | 680 | 125 | FIGURE | YES |
| NUMBER OF LANES | 1 | 1 | 4.5 | NO |

| SUMMARY OF WARRANTS SATISFIED | | | | | |
|---|---|---|---|---|---|
| WARRANT 1 | | WARRANT 5 | | WARRANT 9 | |
| WARRANT 2 | | WARRANT 6 | | WARRANT 10 | |
| WARRANT 3 | | WARRANT 7 | | WARRANT 11 | |
| WARRANT 4 | | WARRANT 8 | | TOTAL = | 0 |

# SITE

# NUMBER

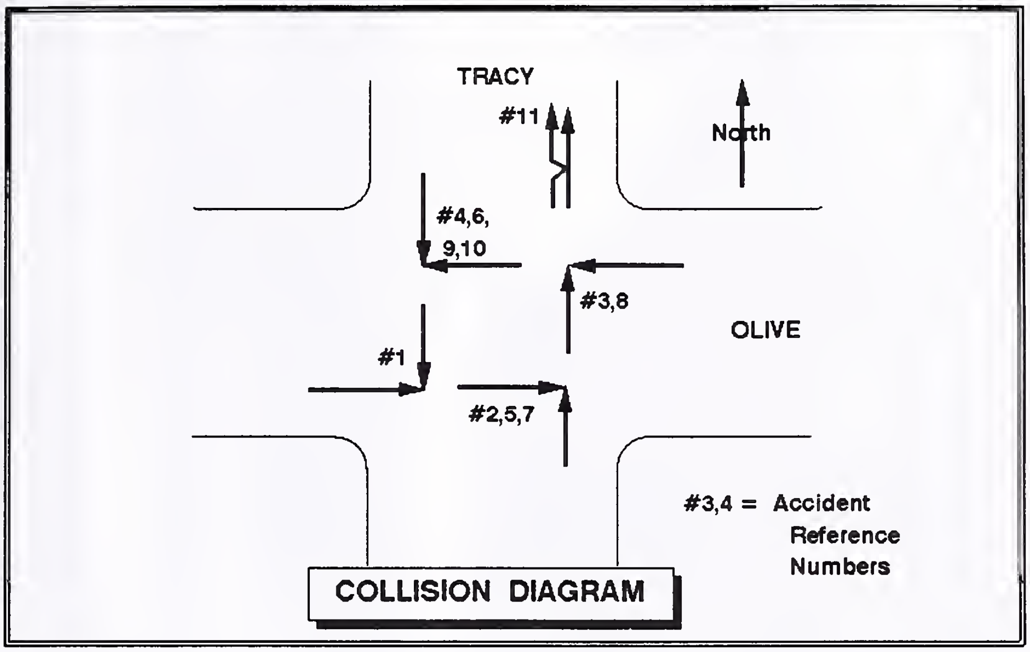
# 12

# OLIVE

# and

# TRACY

# ACCIDENT SUMMARY
## OLIVE & TRACY




### ACCIDENT KEY

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ANGLE | 7 | 26 | 88 | 2045 | INJURY | CLEAR | DRY | DAY |
| 2 | ANGLE | 11 | 25 | 88 | 1240 | PROP DAM | CLEAR | DRY | DAY |
| 3 | ANGLE | 11 | 26 | 88 | 1320 | PROP DAM | SNOW | ICY | DAY |
| 4 | ANGLE | 12 | 27 | 89 | 1346 | PROP DAM | CLEAR | ICY | DAY |
| 5 | ANGLE | 3 | 1 | 90 | 1812 | PROP DAM | CLEAR | DRY | NITE |
| 6 | ANGLE | 8 | 13 | 90 | 1220 | PROP DAM | CLEAR | DRY | DAY |
| 7 | ANGLE | 5 | 2 | 91 | 1825 | PROP DAM | RAIN | WET | NITE |
| 8 | ANGLE | 9 | 13 | 91 | 701 | PROP DAM | CLEAR | DRY | DAY |
| 9 | ANGLE | 12 | 20 | 91 | 834 | PROP DAM | CLEAR | DRY | DAY |
| 10 | ANGLE | 12 | 23 | 91 | 834 | INJURY | CLEAR | DRY | DAY |
| 11 | SIDESWIPE | 2 | 8 | 88 | 941 | PROP DAM | CLEAR | SNOW | DAY |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

### ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 4 | 1988 | #INJ ACC | 2 |
| 1 | 1989 | #FAT ACC | 0 |
| 2 | 1990 | #PDO ACC | 9 |
| 4 | 1991 | PERSON = | 2 * |
| 11 | TOTAL | NIGHTIME | 13% |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 10 | DRY | 73% |
| REAR END | 0 | WET | 9% |
| SIDESWIPE | 1 | SNOW | 0% |
| LEFT TRN | 0 | ICE | 18% |
| OTHER | 0 | OTHER | 0% |

Looking North

TRACY

Looking South

Looking East

OLIVE

Looking West

## TRAFFIC OPERATIONS

Olive is a local east-west street which runs Parallel to Babcock, a one-way eastbound arterial. Olive Street, in the area of this study site, is the southern boundary of the Bozeman CBD area. Tracy is a local north-south street. Their intersection is one block north of another study site at Tracy and Curtiss. This intersection is also one of three consecutive intersections on Olive which are discussed in the "street corridors" section of this report.

The geometry of this intersection is characterized by varying street widths. Olive to the west is 36' wide and to the east it is 44 feet wide. The south side of the street maintains a straight alignment. Tracy is 30' wide to the south and 40' wide to the north, while the west side of the street is on a thru alignment.

Being on the fringe of the CBD, parking is very intense in this area. Parking restrictions consists of no parking on the west side of Tracy south of the intersection; no parking zones at corners; loading zone restrictions; and no parking between certain hours on certain days. Very few of these parking zones add to the safety or efficiency of this intersection.

The intersection is currently controlled by yield signs on Tracy. Traffic volumes are very high considering that these are local streets. Turning movements at the intersection are also very high, which indicates the amount or circulation traffic that uses this intersection. Other than the yield signs there are no other markings or signs to indicate proper operation of this intersection.

Surrounding land use includes a church in the northwest corner. This church is only set back from the sidewalk by a distance of 4-5' and presents an imposing sight obstruction. The parking lot for the Federal Building is located in the northeast corner and access points to this lot are near the corner of the intersection. Two other large buildings are located in the southwest and southeast corners of the intersection. Both of these buildings are within the sight triangle required for yield control at intersections. Traffic speeds are low on the intersection approaches, especially during peak hours of the day. Even if the 85th percentile speed on these streets were 20 mph, the buildings located in the corners would be within a required sight triangle of 90 feet.

Observed traffic operations at this intersection point to numerous problems directly related to safety and efficiency. Despite the presence of a yield sign, all southbound traffic stops because there is absolutely no safe line of vision. A significant portion of northbound traffic also stops for a similar reason. East-west traffic has a surprising number of vehicles who stop for the intersection, probably because drivers are just not sure of who has the right-of-way.

During peak periods the intersection becomes quite congested even though traffic volumes are not extremely high. Significant turning movements are usually the cause of congestion, but vehicles also become backed up by access problems to the Federal Building parking lot on Tracy north of the intersection. Conflicts and near accidents were noted during peak hour traffic observation periods. Turning vehicles waiting in the traffic lanes are skirted on both sides and the turning vehicle provides a temporary sight restriction to vehicles entering from the side street. The offset street widths also create opportunities for drivers to make errant moves which result in conflicts.

A significant number of pedestrians also cross at this intersection during peak traffic periods. It was observed the pedestrians usually yield to vehicles because of the chaotic operations. Drivers have enough decisions to make during these periods without accommodating pedestrians and this situation is normally obvious to the pedestrian.

There were 10 angle accidents and 1 sideswipe accident at this intersection during the reporting period. The vast majority of accidents were on dry roads during the daylight hours. There were two injuries attributed to these accidents. The injury rate is low for the type of accidents involved, probably because of the lower speeds.

## IMPROVEMENTS

Permanent sight restrictions exist in all corners of this intersection. Since uncontrolled and yield intersections require a sight triangle 110' on a side for traffic speeds up to 25 mph, this intersection warrants stop control. The existing yield signs must be replaced with stop signs, located for maximum visibility.

The next most critical improvement required at this intersection would be minimizing the street width offsets. Construction of a sidewalk bulb in the northeast corner of the intersection would reduce the disparity in street widths and provide a shorter, more visible pedestrian crossing. Properly design, the new corner radius would allow uniform pavement markings to accommodate left turn bays on Olive Street. This action would improve efficiency of the intersection and eliminate errant conflict movements during peak traffic periods. New markings on both streets including stop bars, crosswalks and centerlines will provide positive guidance and assure drivers of the proper intersection operation. Implementation of these improvements will necessarily remove a significant number of parking spaces, but will save a substantial amount of money, pain and suffering.

Long term improvements at this intersection are discussed in the "Street Corridors" section of this report. One other improvement not mentioned in that section would be modifications to the Federal Building parking lot and access points. A great deal of delay and conflict is related to activities in and around that lot. The best solution, in the long term, may be construction of more off-street parking with proper access control. The City may also want to begin discussions with Federal Building officials regarding truck access and circulation in this area.

# OLIVE & TRACY

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 4100 |
| SOUTH APP | 1900 |
| EAST APP | 4000 |
| WEST APP | 4000 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | |
| YIELD | YES |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | YES |
| MARKING | YES |
| WARNING | YES |
| REGULATORY | YES |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $9,090 |
| MDoT FUND | $4,660 |
| CITY FUND | $4,430 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 1.2 | 60% |
| PDO | 5.1 | 57% |

**BENEFIT/COST RATIO:** 5

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 69 | 4 |
| ACCIDENT RATE | 26 | 15 |
| SEVERITY | 43 | 13 |
| VOL/CAPACITY | 68 | 3 |
| SIGHT DIST. | 87 | 9 |
| DRIVER EXPECT | 100 | 1 |
| INFO DEFICIENT | 92 | 1 |
| HAZARD INDEX | 62.6 | 4 |
| B/C RATIO | 33 | 17 |

| | | |
|---|---|---|
| PRIORITY | 52.8 | 12 |

# SITE

# NUMBER

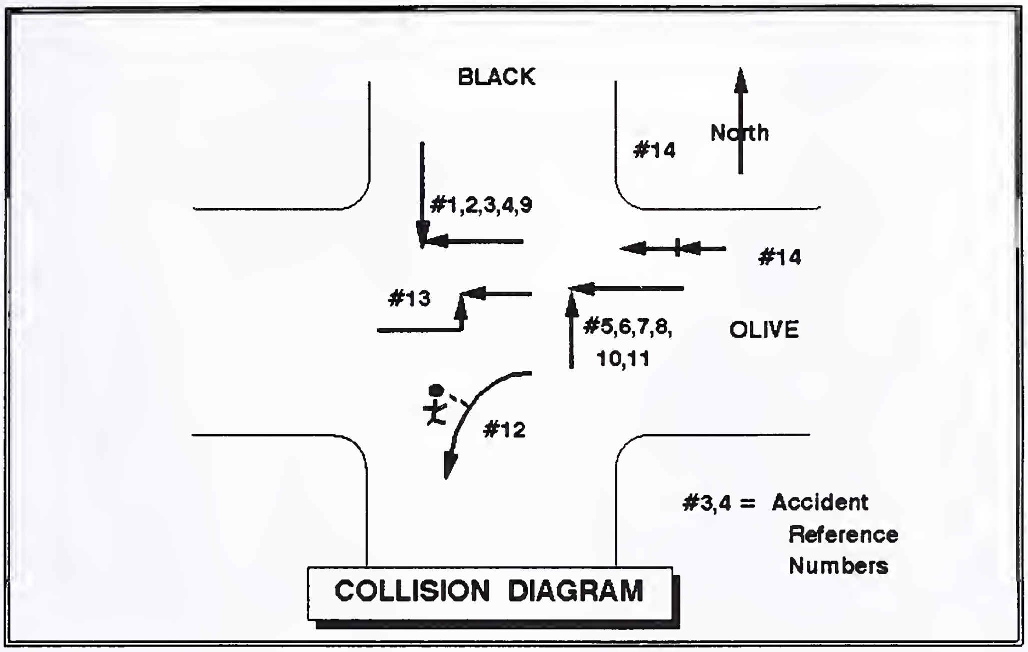
# 13

# OLIVE

# and

# BLACK

# ACCIDENT SUMMARY
## OLIVE & BLACK




| ACC NO. | ACCIDENT TYPE | ACCIDENT KEY MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ANGLE | 8 | 6 | 88 | 859 | INJURY | CLEAR | DRY | DAY |
| 2 | ANGLE | 9 | 8 | 88 | 1710 | PROP DAM | CLEAR | DRY | DAY |
| 3 | ANGLE | 10 | 1 | 88 | 1632 | PROP DAM | CLEAR | DRY | DAY |
| 4 | ANGLE | 8 | 20 | 89 | 1555 | PROP DAM | CLEAR | DRY | DAY |
| 5 | ANGLE | 8 | 21 | 89 | 1321 | PROP DAM | CLEAR | DRY | DAY |
| 6 | ANGLE | 12 | 4 | 89 | 1233 | PROP DAM | CLEAR | WET | DAY |
| 7 | ANGLE | 1 | 19 | 90 | 1900 | PROP DAM | CLEAR | ICY | NITE |
| 8 | ANGLE | 6 | 8 | 90 | 1045 | PROP DAM | CLEAR | DRY | DAY |
| 9 | ANGLE | 1 | 19 | 91 | 959 | PROP DAM | CLEAR | SNOW | DAY |
| 10 | ANGLE | 6 | 1 | 91 | 1815 | PROP DAM | CLEAR | DRY | DAY |
| 11 | ANGLE | 11 | 14 | 91 | 1750 | INJURY | CLEAR | ICY | NITE |
| 12 | FELL OUT VEH | 8 | 10 | 91 | 209 | INJURY | CLEAR | DRY | NITE |
| 13 | LEFT TURN | 10 | 6 | 89 | 1800 | PROP DAM | CLEAR | DRY | DAY |
| 14 | REAREND | 12 | 23 | 89 | 1537 | PROP DAM | CLEAR | ICY | DAY |

### ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 3 | 1988 | #INJ ACC | 3 |
| 5 | 1989 | #FAT ACC | 0 |
| 2 | 1990 | #PDO ACC | 11 |
| 4 | 1991 | PERSON = | 3 * |
| 14 | TOTAL | NIGHTIME | 21% |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 11 | DRY | 64% |
| REAR END | 1 | WET | 7% |
| SIDESWIPE | 0 | SNOW | 7% |
| LEFT TRN | 1 | ICE | 21% |
| OTHER | 1 | OTHER | 0% |

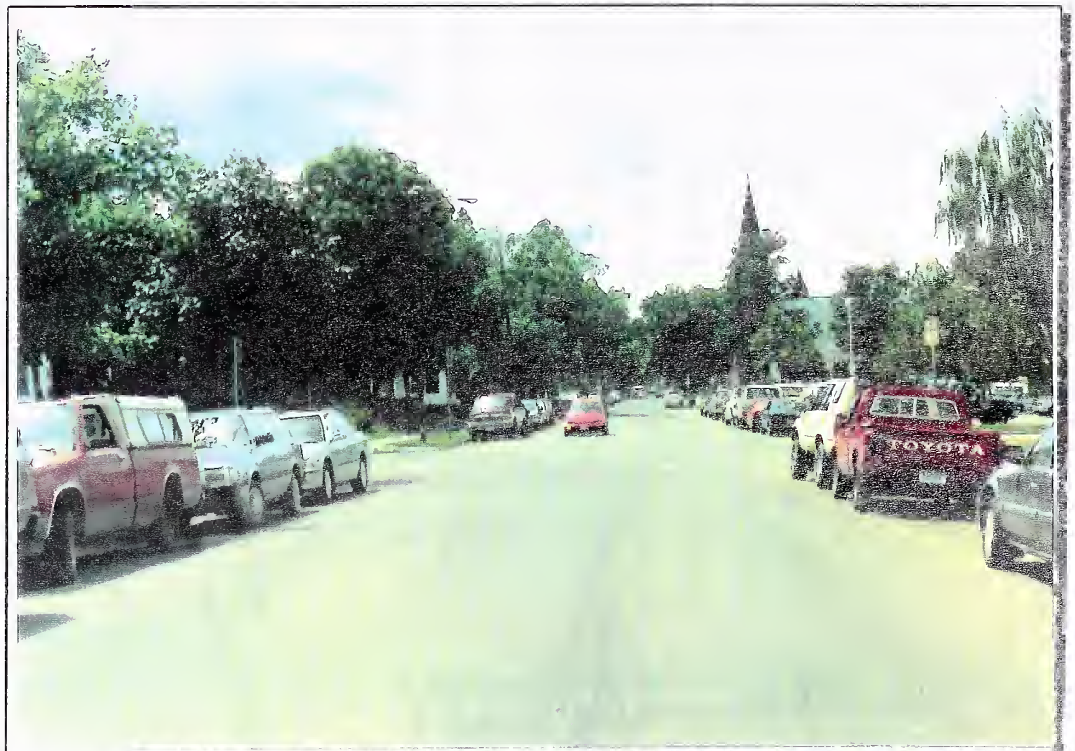
BLACK

Looking North

Looking South

OLIVE

Looking East




Looking West

## TRAFFIC OPERATIONS

Olive is a local east-west street which runs Parallel to Babcock, a one-way eastbound arterial. Olive Street, in the area of this study site, is the southern boundary of the Bozeman CBD area. Black is a local north-south street. Their intersection is one block east of another study site at Olive and Tracy. This intersection is also one of three consecutive intersections on Olive which are discussed in the "street corridors" section of this report.

The geometry of this intersection is characterized by varying street widths. Olive to the west is 44' wide and to the east it is 34 feet wide. Black is 30' wide to the south and 40' wide to the north.

Being on the fringe of the CBD, parking is very intense in this area. Parking restrictions consists of no parking on the east side of Black south of the intersection; no parking zones at corners; and no parking between certain hours on certain days. Very few of these parking zones add to the safety or efficiency of this intersection.

The intersection is currently an uncontrolled intersection. Traffic volumes are very high considering that these are local streets. Turning movements at the intersection are significant with the predominant turn being the southbound right. There are no other markings or signs to indicate proper operation of this intersection.

Surrounding land use is composed of a a parking lot for the Federal Building in the northwest corner and multi-story buildings in the remaining corners. All of these buildings are within the sight triangle required for an uncontrolled intersection. Traffic speeds are low on the intersection approaches especially during peak hours of the day. Even if the 85th percentile speed on these streets were 20 mph, the buildings located in the corners would still be within a required sight triangle of 90 feet.

Observed traffic operations at this intersection point to numerous problems directly related to safety and efficiency. Westbound traffic approaches the intersection with the highest degree of caution since the driver's line of sight is obviously impeded on both sides. The predominant Black Avenue movement, the southbound right turn, is also the movement which drivers exercise the

least amount of caution. Southbound thru drivers exhibit due caution because of the imposing buildings and parked cars blocking their line of sight. Offset street widths amplifies the sight distance restrictions at this intersection and creates opportunities for drivers to make errant moves resulting in conflicts.

A significant number of pedestrians also cross at this intersection during peak traffic periods. It was observed the pedestrians exercise due caution when crossing this intersection because restricted sight distances and uncontrolled vehicular traffic.

There were 11 angle accidents and 3 other type accidents at this intersection during the reporting period. The majority of accidents were on dry roads during the daylight hours. There were three injuries attributed to these accidents. The injury rate is low for the type of accidents involved, probably because of the lower speeds.

## IMPROVEMENTS

Permanent sight restrictions exist in all corners of this intersection. Since uncontrolled and yield intersections require a sight triangle 110' on a side for traffic speeds up to 25 mph, this intersection warrants stop control. The new stop signs should be placed on the lower volume Black Avenue approaches and located for maximum visibility.

The next most critical improvement required at this intersection would be minimizing the street width offsets. Construction of a sidewalk bulbs in all corners of the intersection would provide shorter, more visible pedestrian crossings and reduce the number of parking spaces that would have to be eliminated from Olive Street. Properly design, the new corner radii would restrict errant vehicle movements within the intersection area and improve overall traffic operations on the approaches. New markings on both streets including stop bars, crosswalks and centerlines will provide positive guidance and assure drivers of the proper intersection operation. The bulb islands on the east side of the intersection will present an opportunity to install some low growth landscaping or other aesthetic improvements.

Long term improvements at this intersection is discussed in the "Street Corridors" section of this report.

# OLIVE & BLACK

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 2500 |
| SOUTH APP | 1600 |
| EAST APP | 3000 |
| WEST APP | 4000 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | YES |
| MARKING | YES |
| WARNING | YES |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $11,060 |
| MDoT FUND | $1,760 |
| CITY FUND | $9,300 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 1.2 | 40% |
| PDO | 5.6 | 51% |

**BENEFIT/COST RATIO:** 4

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 76 | 2 |
| ACCIDENT RATE | 38 | 11 |
| SEVERITY | 45 | 11 |
| VOL/CAPACITY | 57 | 4 |
| SIGHT DIST. | 72 | 17 |
| DRIVER EXPECT | 92 | 2 |
| INFO DEFICIENT | 79 | 4 |
| HAZARD INDEX | 62.2 | 5 |
| B/C RATIO | 30 | 18 |

| | | |
|---|---|---|
| PRIORITY | 51.6 | 13 |

# SITE

# NUMBER

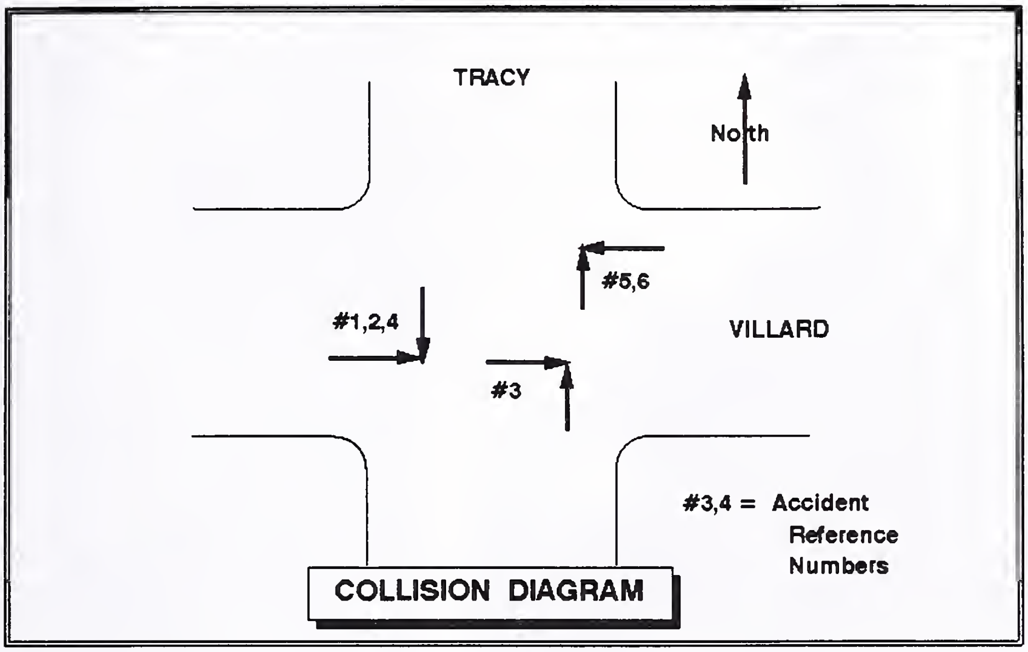
# 14

# VILLARD

# and

# TRACY

# ACCIDENT SUMMARY
# VILLARD & TRACY




## ACCIDENT KEY

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ANGLE | 6 | 12 | 88 | 1630 | PROP DAM | CLEAR | DRY | DAY |
| 2 | ANGLE | 12 | 11 | 89 | 1259 | PROP DAM | CLEAR | ICY | DAY |
| 3 | ANGLE | 3 | 23 | 90 | 1200 | INJURY | CLEAR | SNOW | DAY |
| 4 | ANGLE | 6 | 26 | 90 | 1049 | PROP DAM | CLEAR | DRY | DAY |
| 5 | ANGLE | 11 | 5 | 90 | 1950 | PROP DAM | CLEAR | ICY | NITE |
| 6 | ANGLE | 11 | 20 | 91 | 1010 | PROP DAM | ALEAR | DRY | DAY |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

## ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 1 | 1988 | #INJ ACC | 1 |
| 1 | 1989 | #FAT ACC | 0 |
| 3 | 1990 | #PDO ACC | 5 |
| 1 | 1991 | PERSON = | 1 * |
| 6 | TOTAL | NIGHTIME | 17% |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 6 | DRY | 50% |
| REAR END | 0 | WET | 0% |
| SIDESWIPE | 0 | SNOW | 17% |
| LEFT TRN | 0 | ICE | 33% |
| OTHER | 0 | OTHER | 0% |

Looking North

**TRACY**

Looking South

Looking East

**VILLARD**

Looking West

## TRAFFIC OPERATIONS

Villard and Tracy are two local streets which intersect in a residential area near the old Bozeman hospital. Villard is an east-west street and Tracy Avenue is a north-south street. Villard is 34 feet wide and Tracy is 30 feet in width. Parking demand in the area is high except that Tracy is so narrow that parking is prohibited on the east side of the street. Trees in the boulevard area are large and well trimmed on Tracy. They are overgrown and imposing on Villard. Trees on the east side of the intersection obstruct the line of sight for that approach. Narrow street right-of-way and inadequate building setbacks at this intersection are typical of many Bozeman intersections. There are permanent sight obstructions in all corners due to houses, buildings and parking lots. The required sight distance for an uncontrolled intersection and 25 mph vehicle operating speeds is 110 feet. It was determined that a permanent structure in each corner of the intersection encroaches upon the sight triangle required for an uncontrolled intersection.

It was observed that 90% of the east-west traffic on Villard stops before entering the intersection. Significantly less drivers stop or even slow while traveling on Tracy.

There were six angle accidents at this intersection during the reporting period. Fifty percent of them were on dry streets and 5 were during daylight hours.

## IMPROVEMENTS

Since permanent sight restrictions exist in all corners of this intersection and there is sufficient evidence that it cannot function reasonably well as an uncontrolled intersection, vehicle right-of-way control is indicated. Yield signs cannot be used because yield signs require the same unobtrusive line of sight that is necessary for uncontrolled intersections. Therefore, stop sign control is recommended for the lesser volume, Villard Street. Trees on the approach to the new stop sign installation should be trimmed to provide an unimpeded view of the stop signs and no parking zones should be marked to allow adequate sight distance for vehicles cross Tracy from a stopped position.

Long term improvements are not considered viable at this site.

# VILLARD & TRACY

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 1600 |
| SOUTH APP | 1400 |
| EAST APP | 600 |
| WEST APP | 700 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | YES |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $1,211 |
| MDoT FUND | $1,011 |
| CITY FUND | $200 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 0.8 | 60% |
| PDO | 3.0 | 60% |

**BENEFIT/COST RATIO:** 9

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 54 | 16 |
| ACCIDENT RATE | 41 | 10 |
| SEVERITY | 43 | 16 |
| VOL/CAPACITY | 23 | 14 |
| SIGHT DIST. | 81 | 12 |
| DRIVER EXPECT | 67 | 9 |
| INFO DEFICIENT | 75 | 9 |
| HAZARD INDEX | 52.6 | 14 |
| B/C RATIO | 47 | 11 |

| | | |
|---|---|---|
| PRIORITY | 50.8 | 14 |

# SITE

# NUMBER

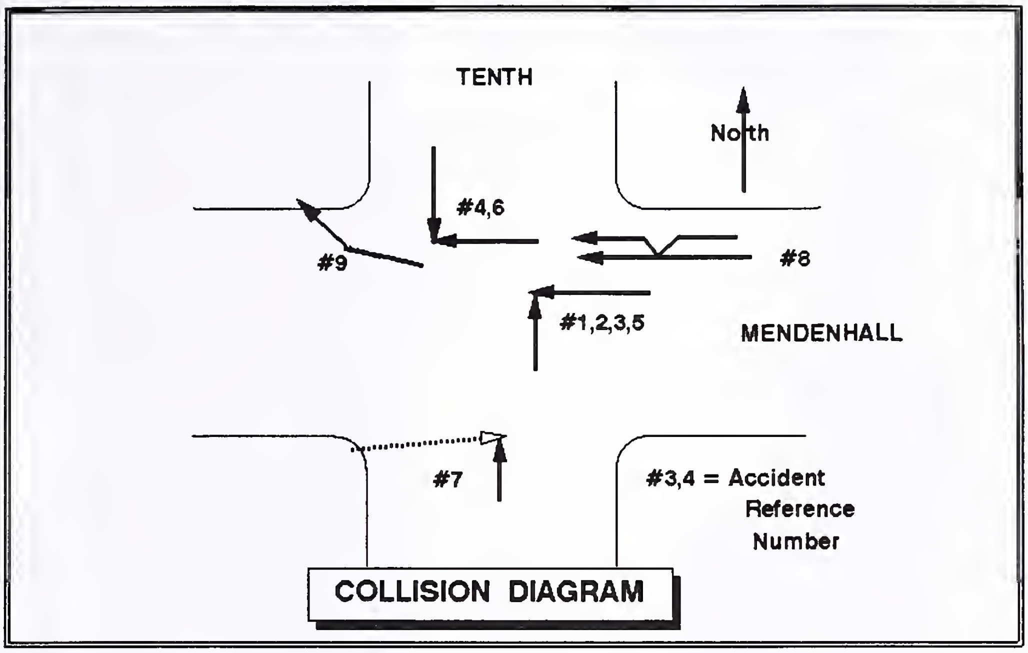
# 15

# MENDENHALL

# and

# TENTH

# ACCIDENT SUMMARY
## MENDENHALL & TENTH




COLLISION DIAGRAM

### ACCIDENT KEY

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ANGLE | 1 | 15 | 88 | 1205 | PROP DAM | SNOW | ICY | DAY |
| 2 | ANGLE | 12 | 3 | 88 | 1535 | INJURY | CLEAR | WET | DAY |
| 3 | ANGLE | 4 | 16 | 89 | 1540 | PROP DAM | CLEAR | DRY | DAY |
| 4 | ANGLE | 10 | 25 | 90 | 933 | PROP DAM | CLEAR | DRY | DAY |
| 5 | ANGLE | 2 | 15 | 91 | 1030 | PROP DAM | CLEAR | DRY | DAY |
| 6 | ANGLE | 5 | 7 | 91 | 1235 | PROP DAM | RAIN | WET | DAY |
| 7 | PEDESTRIAN | 11 | 20 | 90 | 1210 | PROP DAM | CLEAR | ICY | DAY |
| 8 | SIDESWIPE | 10 | 3 | 88 | 1205 | PROP DAM | CLEAR | DRY | DAY |
| 9 | SINGLE VEH | 4 | 6 | 90 | 200 | PROP DAM | CLEAR | DRY | NITE |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

### ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 3 | 1988 | #INJ ACC | 1 |
| 1 | 1989 | #FAT ACC | 0 |
| 3 | 1990 | #PDO ACC | 8 |
| 2 | 1991 | PERSON = | 1 * |
| 9 | TOTAL | NIGHTIME | 11% |

* No. of Persons Injured

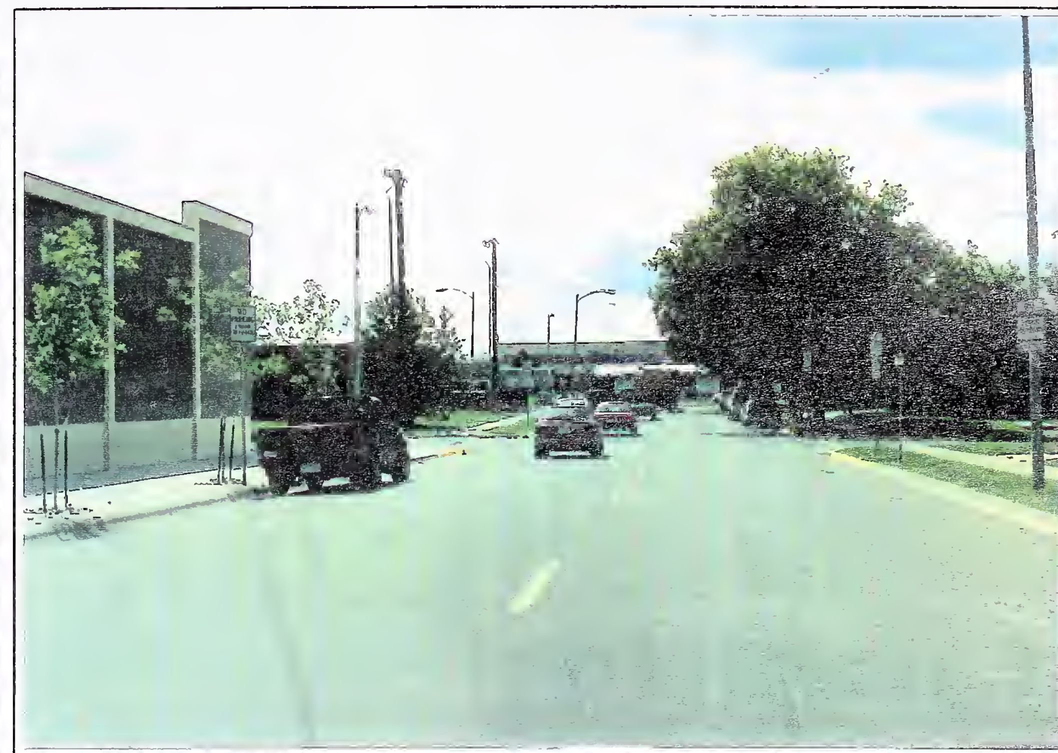
| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 6 | DRY | 56% |
| REAR END | 0 | WET | 22% |
| SIDESWIPE | 1 | SNOW | 0% |
| LEFT TRN | 0 | ICE | 22% |
| OTHER | 2 | OTHER | 0% |


Looking North

Looking South

TENTH


Looking East



Looking West

MENDENHALL

## TRAFFIC OPERATIONS

Mendenhall is an east-west arterial which runs parallel to and north of Main Street, a major arterial. Mendenhall is also a one-way westbound street which purportedly compliments Babcock, a one-way eastbound arterial south of Main. Its intersection with Tenth, a local north-south street is two blocks west of 7th Avenue, a major north-south arterial. This section of Mendenhall is only three blocks long. Mendenhall terminates at Eleventh Avenue, at a T-intersection in front of Bozeman High School. Eleventh is a north-south arterial and the intersection of Mendenhall and Eleventh is not signalized, while the intersection of Seventh and Mendenhall is signalized.

Mendenhall has two lanes of traffic with parking on both sides within a 38' street section. Tenth has two lanes of traffic and parking on both sides within a 38' section. Stop signs exist on the Tenth Avenue approaches. Other signs at the intersection include parking signs, one-way signs and street name signs. Sign placement and parking restrictions are not entirely adequate for the conditions encountered at this intersection. Parking demand in this area is quite heavy and no parking zones provide less than minimum clearance at the intersection.

Traffic volumes at this location are relatively high. Most of the traffic is either bypassing congested intersections on Main Street or circulating from adjacent businesses. Pedestrian traffic was not significant during the traffic counting period but does become quite heavy when teenagers are accessing fast food restaurants east of the intersection from the high school.

Operational observations indicate that this area can become quite congested and traffic from the signal at Eleventh backs up into the Tenth Avenue intersection during peak hours. There is only one left turn lane at the Eleventh street intersection while 95% of the traffic on Mendenhall turns left at this intersection. Also, there is significant lane changing within the Tenth Avenue intersection area because of the traffic demand movement and the lane assignments at Eleventh. Traffic on the Tenth approaches can cross or gain access to Mendenhall with gaps from the signal at Seventh Avenue. However, sight distance to the east from those approaches is obstructed by vehicles parked along Mendenhall. Southbound drivers also loose sight of the stop sign because of parked vehicles and a tree in the northwest corner of the intersection.

There were 6 angle, 1 sideswipe, 1 pedestrian and 1 single vehicle accident at this intersection during the reporting period. Less than ideal street conditions were involved in less than half of the accidents. The majority of accidents occurred during the noon hour.

## IMPROVEMENTS

Recommended improvements attempt to satisfy most of the operating requirements at this intersection. The sight distance problem from the Tenth Avenue approach legs must be solved by signing and marking adequate no parking zones back from the curb radii. Also, no parking within 30 feet of the stop signs should be signed and marked along with trimming of trees to allow reasonable visibility of the signs.

Since there are marked crosswalks in this area it is desirable to install warning signs to mark the crossing locations. Marking of a solid lane divider line on the Mendenhall approach will reinforce the lane change restriction within the intersection area. Marking of a centerline on Tenth will help guide drivers to align their vehicles at the proper position on the Tenth Avenue approaches. Right and left turn lane only signs will reinforce proper lane designations when pavement marks are covered by snow and ice.

Turn restriction signs for Tenth traffic as per the MUTCD guidelines are required even though no wrong way accidents have been reported at this location.

Long term improvements at this location are highly dependent on future transportation projects within the Bozeman urban area. Proposed facilities should relieve traffic growth in this area. Congestion and safety could also be improved significantly if modifications to the Eleventh Avenue intersection allowed a double left turn from Mendenhall. This could be accomplished with signing and pavement markings only when a future traffic signal is warranted and installed. This action would greatly reduce queue build-up and improve operations on Eleventh Avenue as well.

# MENDENHALL & TENTH

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 400 |
| SOUTH APP | 1300 |
| EAST APP | 5700 |
| WEST APP | 4800 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | |
| YIELD | |
| STOP | YES |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | YES |
| WARNING | YES |
| REGULATORY | YES |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $2,010 |
| MDoT FUND | $1,900 |
| CITY FUND | $110 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 0.6 | 60% |
| PDO | 3.3 | 41% |

**BENEFIT/COST RATIO:** 6

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 64 | 8 |
| ACCIDENT RATE | 23 | 16 |
| SEVERITY | 40 | 18 |
| VOL/CAPACITY | 41 | 6 |
| SIGHT DIST. | 100 | 1 |
| DRIVER EXPECT | 67 | 11 |
| INFO DEFICIENT | 89 | 2 |
| HAZARD INDEX | 54.1 | 13 |
| B/C RATIO | 37 | 14 |

| | | |
|---|---|---|
| PRIORITY | 48.5 | 15 |

# SITE

# NUMBER

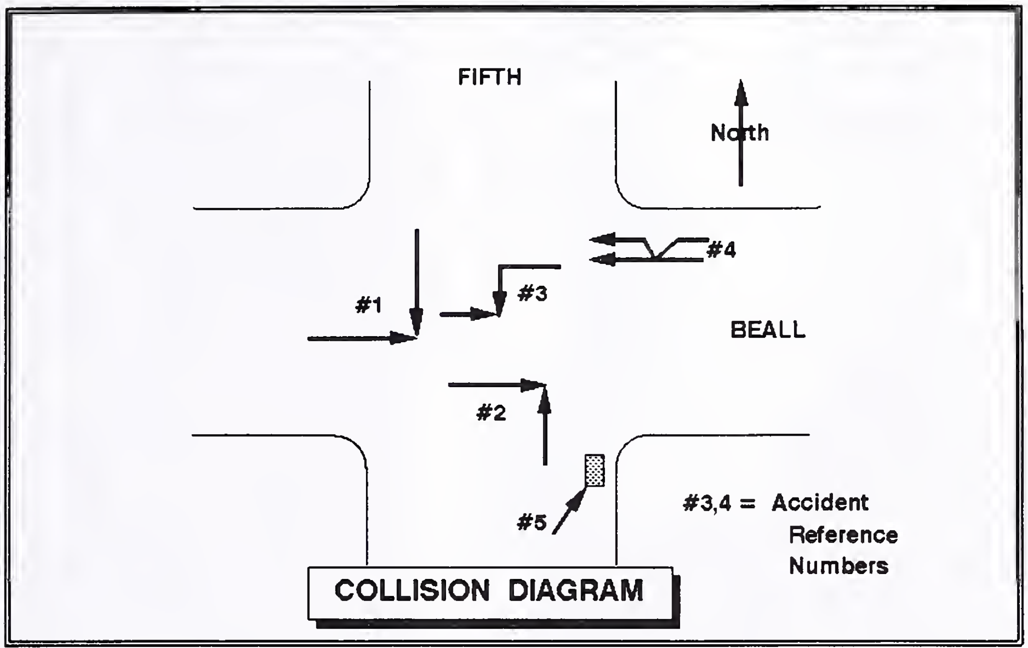
# 16

# BEALL

# and

# FIFTH

# ACCIDENT SUMMARY
## BEALL & FIFTH



COLLISION DIAGRAM

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| | | ACCIDENT KEY | | | | | | | |
| 1 | ANGLE | 11 | 15 | 88 | 1657 | PROP DAM | SNOW | ICY | NITE |
| 2 | ANGLE | 4 | 8 | 90 | 1125 | INJURY | CLEAR | WET | DAY |
| 3 | LEFT TURN | 9 | 10 | 90 | 1101 | INJURY | CLEAR | DRY | DAY |
| 4 | PARKED CAR | 2 | 8 | 89 | 1726 | PROP DAM | CLEAR | ICY | NITE |
| 5 | SIDESWIPE | 9 | 5 | 91 | 2205 | PROP DAM | CLEAR | DRY | NITE |
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### ACCIDENT STATISTICS

| NO. ACC. | YEAR | | | |
|---|---|---|---|---|
| 1 | 1988 | #INJ ACC | 2 | |
| 1 | 1989 | #FAT ACC | 0 | |
| 2 | 1990 | #PDO ACC | 3 | |
| 1 | 1991 | PERSON = | 2 | * |
| 5 | TOTAL | NIGHTIME | 60% | |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 2 | DRY | 40% |
| REAR END | 0 | WET | 20% |
| SIDESWIPE | 1 | SNOW | 0% |
| LEFT TRN | 1 | ICE | 40% |
| OTHER | 1 | OTHER | 0% |

Looking North

FIFTH


Looking South

Looking East

BEALL

Looking West

## TRAFFIC OPERATIONS

Beall Street is a local east -west street and its intersection with Fifth Avenue is one of four study intersections along the Fifth Avenue corridor north of Mendenhall. Specific conditions and problems in this area can be found in the "Street Corridor" section of this report. Both Beall and Fifth are 36 feet wide. Parking in this area is light to moderate, but as is often the case, it is heaviest at the intersection corners. This appeared to be most critical in advance of the stop signs on Fifth.

The intersection is currently controlled by stop signs on Fifth and carries relative high traffic volumes for local streets. Approach traffic is slightly higher on Beall than on Fifth. Trees in the boulevard area are not as imposing as at other locations. However, there are over grown tree which interfere with clear vision of the stop signs.

There were 2 angle, 1 left turn, 1 sideswipe and 1 parked car accident at this intersection during he reporting period. Only 40% of the accidents occurred on dry roads, and 60% of them were during night driving conditions.

## IMPROVEMENTS

Angle accidents at this intersection were clearly related to visibility of stop signs. The existing stop signs should be replaced by 36"x36" signs and relocated to a point of maximum visibility. Trees should be trimmed on the approaches and no parking zones marked and signed in front of the stop signs. Stop bars and centerline markings should be installed to emphasize the stop condition.

Increased lengths of no parking zones are required on Beall. The restricted parking zone lengths were calculated using a dynamic vehicle model for the conditions existing at this site and are noted on the short term improvement sketch.

Long term improvements at this site would be dependent upon arterial road system improvements as discussed in the "street corridor" section of this report. It is not anticipated that traffic volumes will increase at this site or that any other control will be needed in the future.

# BEALL & FIFTH

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 1400 |
| SOUTH APP | 1200 |
| EAST APP | 1800 |
| WEST APP | 1400 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | |
| YIELD | |
| STOP | YES |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | YES |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $1,240 |
| MDoT FUND | $1,150 |
| CITY FUND | $90 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 0.5 | 25% |
| PDO | 0.7 | 23% |

**BENEFIT/COST RATIO:** 6

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 50 | 18 |
| ACCIDENT RATE | 28 | 13 |
| SEVERITY | 51 | 8 |
| VOL/CAPACITY | 35 | 9 |
| SIGHT DIST. | 100 | 2 |
| DRIVER EXPECT | 50 | 20 |
| INFO DEFICIENT | 75 | 11 |
| HAZARD INDEX | 50.4 | 17 |
| B/C RATIO | 38 | 13 |

| | | |
|---|---|---|
| PRIORITY | 46.3 | 16 |

# SITE

# NUMBER

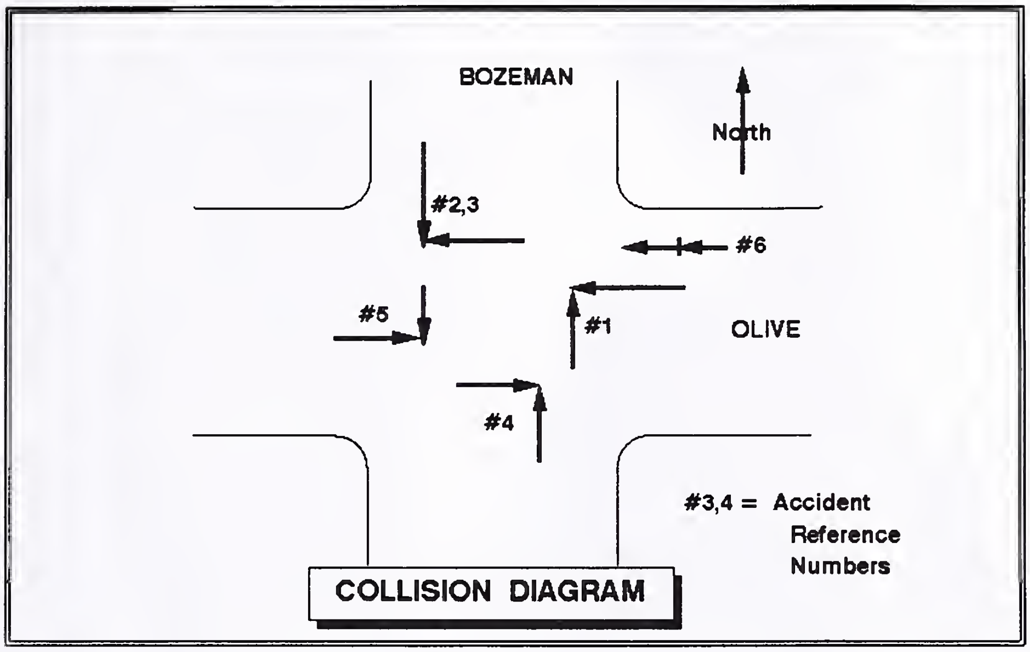
# 17

# OLIVE

# and

# BOZEMAN

# ACCIDENT SUMMARY
# OLIVE & BOZEMAN




COLLISION DIAGRAM

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ANGLE | 6 | 26 | 89 | 1011 | PROP DAM | CLEAR | DRY | DAY |
| 2 | ANGLE | 7 | 31 | 90 | 835 | PROP DAM | CLEAR | DRY | DAY |
| 3 | ANGLE | 8 | 6 | 90 | 1210 | INJURY | CLEAR | DRY | DAY |
| 4 | ANGLE | 2 | 17 | 91 | 1313 | PROP DAM | CLEAR | SNOW | DAY |
| 5 | ANGLE | 10 | 30 | 91 | 1140 | PROP DAM | CLEAR | SNOW | DAY |
| 6 | REAREND | 12 | 14 | 89 | 1205 | PROP DAM | SNOW | ICY | DAY |
| | | | | | | | | | |
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(ACCIDENT KEY)

## ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 0 | 1988 | #INJ ACC | 1 |
| 2 | 1989 | #FAT ACC | 0 |
| 2 | 1990 | #PDO ACC | 5 |
| 2 | 1991 | PERSON = | 1 * |
| 6 | TOTAL | NIGHTIME | 21% |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 5 | DRY | 50% |
| REAR END | 1 | WET | 0% |
| SIDESWIPE | 0 | SNOW | 33% |
| LEFT TRN | 0 | ICE | 17% |
| OTHER | 0 | OTHER | 0% |

Looking North

Looking South

BOZEMAN

Looking East

Looking West

OLIVE

## TRAFFIC OPERATIONS

Olive is a local east-west street which runs Parallel to Babcock, a one-way eastbound arterial. Olive Street, in the area of this study site, is the southern boundary of the Bozeman CBD area. Bozeman is a local north-south street. Their intersection is one block east of another study site at Olive and Black. This intersection is also one of three consecutive intersections on Olive which are discussed in the "street corridors" section of this report.

Both of the streets at this intersection are 34' wide. Being on the fringe of the CBD, parking is very intense in this area but not as great as at the other intersections to the west. Parking restrictions consists of no parking at corners of the intersection. The curb in this area is in bad condition and no yellow curb marks exist.

The intersection is currently an uncontrolled intersection. Traffic volumes are very high considering that these are local streets. Turning movements at the intersection are not significant. The predominant turn is the southbound right with 40% of southbound traffic turning. There are no other markings or signs to indicate proper operation of this intersection.

The intersection is surrounded by residential houses. All but the house in the northeast corner are within the sight triangle required for an uncontrolled intersection. Traffic speeds are higher at this intersection than at the others on Olive. The 85th percentile speed on Olive is greater than 25 mph.

Westbound traffic at this intersection was observed to be the least concerned with lack of sight distance at this location since vehicles approaching in this direction do not slow or even glance sideways. North-south traffic tends to treat the intersection as a stop condition.

A significant number of pedestrians also cross at this intersection during peak traffic periods. Total numbers of pedestrians are not as high as the other Olive Street intersections, but the crossings are definitely higher than at most local intersections.

There were 5 angle accidents and 1 rearend type accident at this intersection during the reporting period. Half of the accidents were on dry roads during the daylight hours. There was one injury attributed to these accidents.

## IMPROVEMENTS

Permanent sight restrictions exist in three corners of this intersection. Since uncontrolled and yield intersections require a sight triangle 110' on a side for traffic speeds up to 25 mph, this intersection warrants stop control. The new stop signs should be placed on the lower volume Bozeman Avenue approaches and located for maximum visibility.

Pavement markings are critical at this intersection to reinforce the stop control condition and to alert drivers to the fact that this intersection has higher than normal pedestrian activity. Markings of stop bars, crosswalks and centerlines on both streets will provide subtle visual clues especially to westbound drivers, that this intersection is different than the preceding intersections encountered.

Parking restrictions near the corners on Olive Street must be modified to account for approach speed of Olive Street traffic. A dynamic vehicle model was used to determine parking setback requirements for vehicles to cross Olive starting from a stopped position on Bozeman.

Long term improvements at this intersection is discussed in the "Street Corridors" section of this report.

# OLIVE & BOZEMAN

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 1600 |
| SOUTH APP | 1000 |
| EAST APP | 2500 |
| WEST APP | 3000 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | YES |
| MARKING | YES |
| WARNING | YES |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $1,980 |
| MDoT FUND | $1,670 |
| CITY FUND | $310 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 0.8 | 60% |
| PDO | 2.8 | 52% |

**BENEFIT/COST RATIO:** 5

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 54 | 15 |
| ACCIDENT RATE | 20 | 17 |
| SEVERITY | 43 | 15 |
| VOL/CAPACITY | 38 | 8 |
| SIGHT DIST. | 72 | 16 |
| DRIVER EXPECT | 75 | 6 |
| INFO DEFICIENT | 75 | 6 |
| HAZARD INDEX | 49.6 | 18 |
| B/C RATIO | 36 | 14 |

| | | |
|---|---|---|
| PRIORITY | 45.1 | 17 |

# SITE

# NUMBER

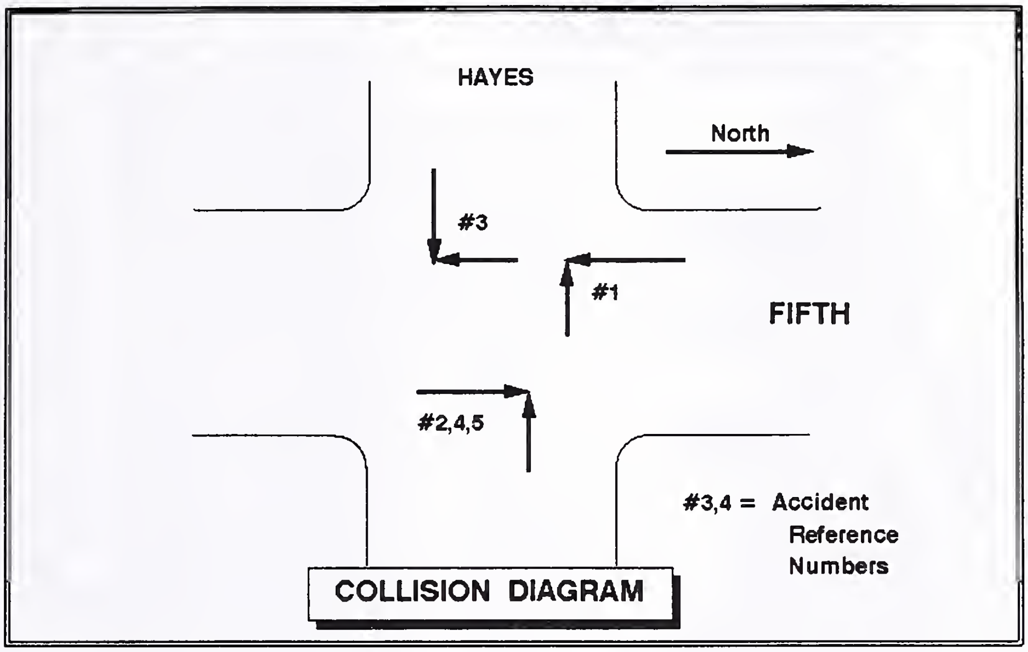
# 18

# HAYES

# and

# FIFTH

# ACCIDENT SUMMARY
## HAYES & FIFTH




| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| | | ACCIDENT KEY | | | | | | | |
| 1 | ANGLE | 2 | 15 | 88 | 1320 | PROP DAM | CLEAR | ICY | DAY |
| 2 | ANGLE | 10 | 15 | 88 | 1734 | PROP DAM | CLEAR | DRY | DAY |
| 3 | ANGLE | 10 | 14 | 89 | 1845 | PROP DAM | CLEAR | DRY | DAY |
| 4 | ANGLE | 3 | 12 | 90 | 1745 | PROP DAM | CLEAR | DRY | DAY |
| 5 | ANGLE | 9 | 20 | 91 | 1319 | PROP DAM | CLEAR | DRY | DAY |
| | | | | | | | | | |
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### ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 2 | 1988 | #INJ ACC | 0 |
| 1 | 1989 | #FAT ACC | 0 |
| 1 | 1990 | #PDO ACC | 5 |
| 1 | 1991 | PERSON = | 0 * |
| 5 | TOTAL | NIGHTIME | 0% |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 5 | DRY | 80% |
| REAR END | 0 | WET | 0% |
| SIDESWIPE | 0 | SNOW | 0% |
| LEFT TRN | 0 | ICE | 20% |
| OTHER | 0 | OTHER | 0% |

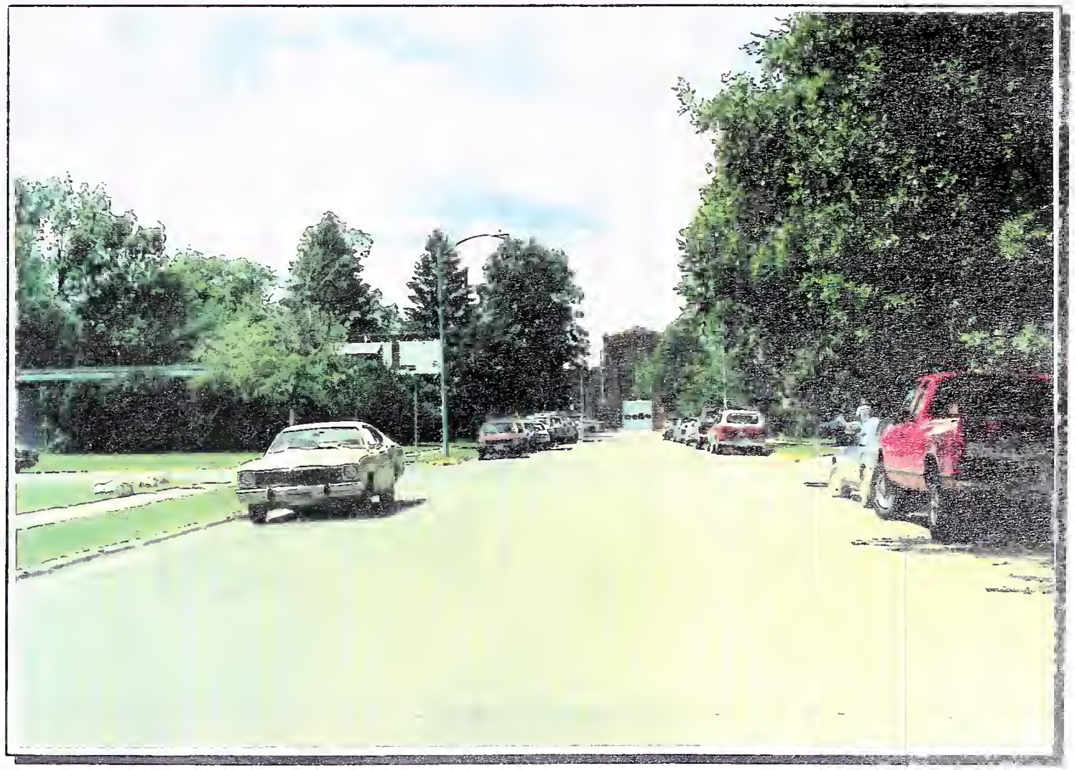
Looking North

FIFTH

Looking South

Looking East

HAYES



Looking West

## TRAFFIC OPERATIONS

Hayes Street is a local east-west and Fifth Avenue is a local north-south street. Their intersection is in the middle of a residential area of Bozeman east of Montana State University. Problems and conditions typical of this area are discussed in the "Street Corridor" section of this report. Street widths are approximately 36 feet. Both streets have boulevards lined with large deciduous trees. Parking is allowed on both sides of the street. Traffic volumes on both streets are low.

The intersection area is relatively wide open. There are low branches on trees in the northeast and northwest corners of the intersection which distracts from the side street view but does not completely block sight distance. This is the only study site which does not have permanent sight obstructions in the form of houses and other structures.

On-street parking appears to be light in the photos, but they were taken in the middle of summer. When the university in is full session, parking is very intense. Yellow curb does exist on the corners but the setback is only half of what it should be. Parking within the yellow zone was observed during different periods of the day.

There were 5 angle accidents reported during the four year period that this study encompassed. The accidents involved most corners of the intersection. The vast majority of accidents were on dry roads in clear weather. All of the accidents occurred between the hours of 2PM and 6PM.

## IMPROVEMENTS

Since no permanent sight restrictions exist at this intersection it is first necessary to remove the temporary sight distance problems. Trees on the north side of the intersection must be trimmed a minimum of 6 feet above the ground and preferably 10 feet. The corner parking restrictions should be extended to 30 feet from the curb radii points.

Yield signs should be installed as a first level control. In this case the signs should be installed on the Hayes Street approach because approach conditions are more suitable for visual recognition of the intersection control signs.

Long term improvements at this location are dependant upon corridor improvements on the east side of Montana State University. No single improvement which could be considered a long term improvement, could be made for this one intersection.

# HAYES & FIFTH

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 700 |
| SOUTH APP | 500 |
| EAST APP | 900 |
| WEST APP | 700 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | YES |
| STOP | |
| WALK | |
| MARKING | |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $330 |
| MDoT FUND | $230 |
| CITY FUND | $100 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 0.0 | 0% |
| PDO | 1.5 | 30% |

**BENEFIT/COST RATIO:** 5

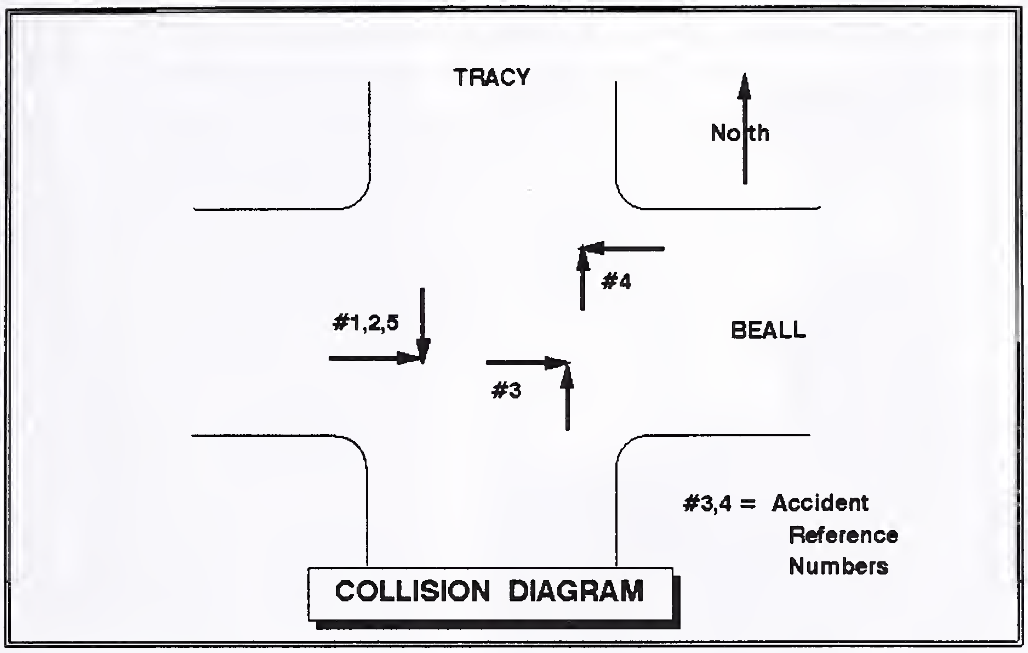
| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 50 | 19 |
| ACCIDENT RATE | 50 | 8 |
| SEVERITY | 34 | 20 |
| VOL/CAPACITY | 12 | 17 |
| SIGHT DIST. | 75 | 14 |
| DRIVER EXPECT | 58 | 18 |
| INFO DEFICIENT | 50 | 20 |
| HAZARD INDEX | 46.7 | 19 |
| B/C RATIO | 34 | 17 |

| | | |
|---|---|---|
| PRIORITY | 42.5 | 18 |

# SITE NUMBER 19

# BEALL and TRACY

# ACCIDENT SUMMARY
## BEALL & TRACY




ACCIDENT KEY

| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ANGLE | 11 | 2 | 88 | 1908 | INJURY | CLEAR | DRY | NITE |
| 2 | ANGLE | 2 | 8 | 90 | 925 | PROP DAM | CLEAR | ICY | DAY |
| 3 | ANGLE | 8 | 8 | 90 | 1115 | PROP DAM | CLEAR | DRY | DAY |
| 4 | ANGLE | 5 | 30 | 91 | 1502 | PROP DAM | RAIN | WET | DAY |
| 5 | ANGLE | 10 | 29 | 91 | 1508 | PROP DAM | CLEAR | ICY | DAY |
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| | | | | | | | | | |

ACCIDENT STATISTICS

| NO. ACC. | YEAR | | | |
|---|---|---|---|---|
| 1 | 1988 | #INJ ACC | 1 | |
| 0 | 1989 | #FAT ACC | 0 | |
| 2 | 1990 | #PDO ACC | 4 | |
| 2 | 1991 | PERSON = | 1 | * |
| 5 | TOTAL | NIGHTIME | 14% | |

* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 5 | DRY | 40% |
| REAR END | 0 | WET | 20% |
| SIDESWIPE | 0 | SNOW | 0% |
| LEFT TRN | 0 | ICE | 40% |
| OTHER | 0 | OTHER | 0% |


Looking North


Looking South

**TRACY**


Looking East


Looking West

**BEALL**

## TRAFFIC OPERATIONS

Beall and Tracy are two local streets which intersect in a residential area near the old Bozeman hospital. Beall is an east-west street and Tracy Avenue is a north-south street. Beall is 44 feet wide on the west side of the intersection and 36 feet wide on the east. Tracy is 30 feet in width. Parking demand in the area is high except that Tracy is so narrow that parking is prohibited on the east side of the street. Trees in the boulevard area are large and well trimmed on Tracy.

A corner "cutoff" approach exists in the southwest corner. This type of a driveway approach is inappropriate under any circumstances. Not only does this type of driveway magnify conflict movements within the intersection, but parked cars in the corner insure inadequate sight distance. Also, parking lots in the northeast and southeast corners of this intersection encroach upon the required sight triangle for an uncontrolled intersection.

Narrow street right-of-way and inadequate building setbacks at this intersection are typical of many Bozeman intersections. There are permanent sight obstructions in all corners due to houses, buildings and parking lots. The required sight distance for an uncontrolled intersection and 25 mph vehicle operating speeds is 110 feet. It was determined that a permanent structure in each corner of the intersection encroaches upon the sight triangle required for an uncontrolled intersection.

It was observed that 70% of the east-west traffic on Beall stops before entering the intersection. Significantly less drivers stop or even slow while traveling on Tracy.

There were five angle accidents at this intersection during the reporting period. Only forty percent of them were on dry streets.

## IMPROVEMENTS

The first and most important improvement that could be recommended at this site would be removal of the corner cutoff driveway. This could be accomplished by removing existing concrete and constructing new curb gutter and sidewalk.

Because of the higher traffic volumes, significant turning movements and observed operation of this intersection, it is recommended that stop signs be installed on the Beall Street approaches. This will require marking and signing additional no parking on Tracy to allow sufficient sight distance for cars stopped on Beall to cross traffic lanes without conflict. Marking stop bars, crosswalks and a short section of centerline on Beall will reinforce the stop condition.

Long term improvements are not considered necessary or viable at this site.

# BEALL & TRACY

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 1700 |
| SOUTH APP | 2100 |
| EAST APP | 1100 |
| WEST APP | 1300 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | YES |
| YIELD | |
| STOP | |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | YES |
| MARKING | YES |
| WARNING | |
| REGULATORY | |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $2,787 |
| MDoT FUND | $2,052 |
| CITY FUND | $735 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 0.8 | 60% |
| PDO | 2.4 | 60% |

**BENEFIT/COST RATIO:** 4

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 50 | 17 |
| ACCIDENT RATE | 26 | 14 |
| SEVERITY | 44 | 12 |
| VOL/CAPACITY | 32 | 10 |
| SIGHT DIST. | 60 | 19 |
| DRIVER EXPECT | 58 | 17 |
| INFO DEFICIENT | 75 | 8 |
| HAZARD INDEX | 46.6 | 20 |
| B/C RATIO | 28 | 19 |

| | | |
|---|---|---|
| PRIORITY | 40.5 | 19 |

# SITE

# NUMBER

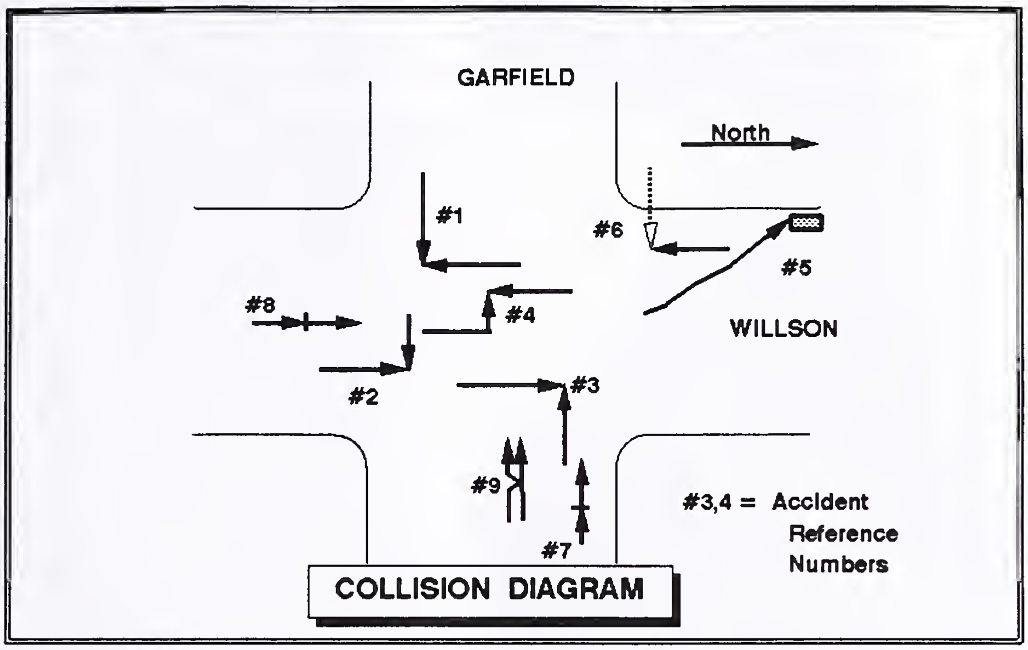
# 20

# GARFIELD

# and

# WILLSON

# ACCIDENT SUMMARY
## GARFIELD & WILLSON




| ACC NO. | ACCIDENT TYPE | MO. | DAY | YEAR | TIME | SEVERITY | WEATHER | ROAD | LIGHT |
|---|---|---|---|---|---|---|---|---|---|
| | | ACCIDENT KEY | | | | | | | |
| 1 | ANGLE | 3 | 3 | 89 | 1234 | PROP DAM | CLEAR | ICY | DAY |
| 2 | ANGLE | 3 | 13 | 90 | 1540 | PROP DAM | SNOW | SNOW | DAY |
| 3 | ANGLE | 11 | 15 | 90 | 1800 | PROP DAM | CLEAR | DRY | NITE |
| 4 | LEFT TURN | 6 | 7 | 88 | 1425 | PROP DAM | CLEAR | DRY | DAY |
| 5 | PARKED CAR | 1 | 5 | 88 | 700 | PROP DAM | CLEAR | ICY | DAY |
| 6 | PEDESTRIAN | 10 | 4 | 89 | 753 | INJURY | SNOW | WET | DAY |
| 7 | REAREND | 2 | 14 | 89 | 859 | PROP DAM | CLEAR | ICY | DAY |
| 8 | REAREND | 11 | 5 | 90 | 1715 | PROP DAM | CLEAR | ICY | NITE |
| 9 | SIDESWIPE | 4 | 4 | 89 | 1720 | PROP DAM | CLEAR | DRY | DAY |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

### ACCIDENT STATISTICS

| NO. ACC. | YEAR | | |
|---|---|---|---|
| 2 | 1988 | #INJ ACC | 1 |
| 4 | 1989 | #FAT ACC | 0 |
| 3 | 1990 | #PDO ACC | 8 |
| 0 | 1991 | PERSON = | 1 * |
| 9 | TOTAL | NIGHTIME | 11% |

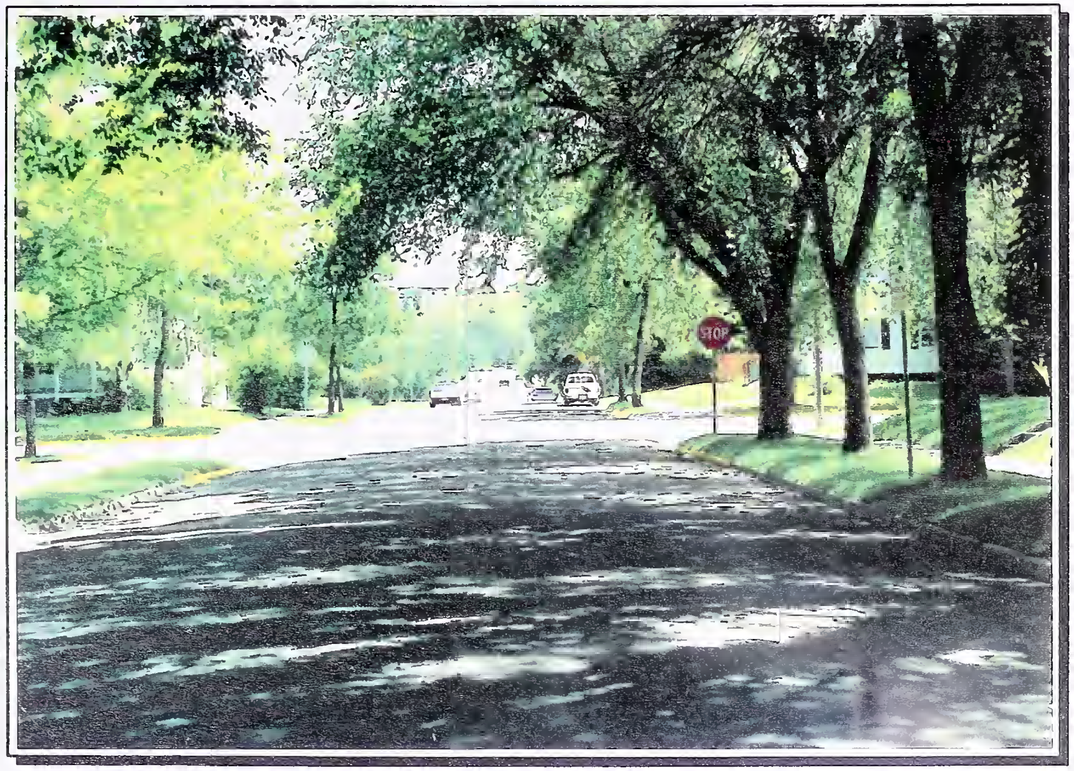
* No. of Persons Injured

| TYPES | NUMBER | ROAD | |
|---|---|---|---|
| ANGLE | 3 | DRY | 34% |
| REAR END | 2 | WET | 11% |
| SIDESWIPE | 1 | SNOW | 11% |
| LEFT TRN | 1 | ICE | 44% |
| OTHER | 2 | OTHER | 0% |

Looking North

WILLSON

Looking South




Looking East

GARFIELD

Looking West

## TRAFFIC OPERATIONS

Willson Avenue is a major north-south arterial within the city of Bozeman. Garfield is a local street which accesses the east side of Montana State University and new residential subdivisions east of Garfield. The intersection is located two and a half blocks east of the university and two blocks north of Grant Street, a major access to the north end of the university. Willson is 44 feet wide and Garfield is 32 feet wide on the west side and 36 feet on the east.

Traffic volumes on Willson are the highest of any of the study sites, in excess of 10,000 ADT. The east leg on Garfield is the higher volume of the side street approaches. Turning movement counts indicate significant southbound left turns and westbound right turns at this intersection. During the observations period, which were not at peak hours, it was noted that some congestion occurs due to the southbound left turn movement. When a vehicle is waiting to make this maneuver, other southbound thru and right turn traffic attempt to pass on the right. This movement present potential conflicts when the right combination of vehicles and street conditions are present.

Gaps in traffic are minimal because of the high volumes on Willson and the absence of any nearby traffic signals. Some side street delay was noted during off peak periods. Pedestrian traffic was significant considering the small number of available gaps.

Existing traffic control at this intersection consists of stop signs on Garfield, street name signs, a crosswalk on the south side, stop bars on Willson, and short sections of yellow curb in all corners. The stop sign in the westbound direction is partially obscured by tree branches.

The most obvious condition at this intersection is the level of congestion and lack of sight distance for vehicles entering from the side street. This situation drives up the frustration level for side street drivers until they are willing to take a chance and accept smaller gaps in the traffic stream than they would normally consider. The driver's ability to adjust to unexpected conflicts under these conditions is minimal and various types of accidents are probable.

There were three angle, two rearend, one sideswipe, one left turn, one pedestrian and one parked car accident at this intersection during the reporting period. Only thirty three percent of them were on dry streets. Icy street conditions accounted for forty four percent of the accident experience. Total accident rate at this intersection is not very high considering the volume of entering traffic.

## IMPROVEMENTS

Because of the high traffic volumes at this intersection, a traffic signal warrant analysis was completed and can be found at the end of this section. None of the eleven signal warrants were met. However, warrant #2, interruption of continuous traffic is within 18% of being met and peak hour delay is also within warrant range. Signals would be warranted in the future if volumes on Willson increase by approximately 20%.

In order to reduce accident potential at this intersection some of the driver decision load must be relieved by improving the efficiency of the intersection. A left turn bay for southbound traffic is considered necessary to improve efficiency and eliminate the potential for blind conflicts created by cars passing on the right in a confined area. Installation of the turn bay would provide an opportunity to mark a painted island on the south side of the intersection and eliminate left turns from the northbound direction, which is an unexpected movement at this intersection. The island could also serve as emergency refuge for pedestrian who don't quite make it across the street because of small traffic gaps. The left turn bay configuration shown in the short term improvement sketch would also serve to eliminate parking within a critical length each side of the intersection on Willson.

Trimming the tree obscuring the westbound stop and installing stop bars, crosswalks and a short section of centerline on both sides of Garfield will reinforce the stop condition and provide positive guidance for vehicles on these approaches.

Long term solutions at this location are dependent upon the transportation plan and eventual implementation of those recommendations. Currently, the plan calls for a raised median in this area of Willson. Considering the volume of left turning traffic from the southbound Willson direction into the subdivision area to the east, it would not be an especially good idea at this intersection. If implemented traffic would be required to access this area via Tracy which would add another 1,000 ADT to Tracy. Other circulation problems may occur if the median blocked this intersection. The recommended short term improvement would accommodate a median as long as a left turn bay was retained in the future.

# GARFIELD & WILLSON

## SITE DATA SUMMARY

**TRAFFIC VOLUMES:**

| | ADT |
|---|---|
| NORTH APP | 10600 |
| SOUTH APP | 8600 |
| EAST APP | 2200 |
| WEST APP | 1000 |

**EXISTING CONTROL:**

| | |
|---|---|
| NONE | |
| YIELD | |
| STOP | YES |
| SIGNAL | |

**RECOMMENDED CONTROL:**

| | |
|---|---|
| PARKING | YES |
| YEILD | |
| STOP | YES |
| WALK | |
| MARKING | YES |
| WARNING | YES |
| REGULATORY | YES |

**ESTIMATED COST:**

| | |
|---|---|
| TOTAL | $4,235 |
| MDoT FUND | $4,185 |
| CITY FUND | $50 |

**% ACCIDENT REDUCTION:**

| | NUMBER | PERCENT |
|---|---|---|
| INJ/FTL | 0.3 | 30% |
| PDO | 3.4 | 43% |

**BENEFIT/COST RATIO:** 2

| | INDEX VALUE | SITE RANK |
|---|---|---|
| # ACCIDENTS | 64 | 7 |
| ACCIDENT RATE | 15 | 19 |
| SEVERITY | 40 | 17 |
| VOL/CAPACITY | 100 | 2 |
| SIGHT DIST. | 96 | 4 |
| DRIVER EXPECT | 67 | 10 |
| INFO DEFICIENT | 67 | 14 |
| HAZARD INDEX | 54.3 | 12 |
| B/C RATIO | 12 | 20 |

| | | |
|---|---|---|
| PRIORITY | 40.3 | 20 |

TRAFFIC SIGNAL WARRANT ANALYSIS
YEAR 1992
GARFIELD & WILLSON

| WARRANT #1 - MINIMUM VEHICULAR VOLUME | | | | | |
|---|---|---|---|---|---|
| 70% WARRANT | | REQUIRED | | EXISTS | |
| YES | NO | MAJOR | MINOR | MAJOR | MINOR |
| 8TH HIGHEST HOUR | | 500 | 150 | 614 | 65 |
| % OF WARRANT MET | | | | 123% | 43% |

| WARRANT #2 - INTERRUPTION OF CONTINOUS TRAFFIC | | | | | |
|---|---|---|---|---|---|
| 70% WARRANT | | REQUIRED | | EXISTS | |
| YES | NO | MAJOR | MINOR | MAJOR | MINOR |
| 8TH HIGHEST HOUR | | 750 | 75 | 614 | 65 |
| % OF WARRANT MET | | | | 82% | 87% |

| WARRANT #3 - MINIMUM PEDESTRIAN TRAFFIC | | | | | |
|---|---|---|---|---|---|
| 50% WARRANT | | REQUIRED | | EXISTS | |
| YES | NO | PEDS | GAPS | PEDS | GAPS |
| FOUR HOURS | | 100 | 60 | 50 | NA |
| PEAK HOUR | | 190 | 60 | 70 | NA |
| % OF WARRANT MET | | | | 37% | ERR |

| | | |
|---|---|---|
| WARRANT #4 - SCHOOL CROSSING [STUD | YES | NO |
| WARRANT #5 - PROGRESSIVE MOVEMENT | YES | NO |
| WARRANT #6 - ACCIDENT EXPERIENCE | YES | NO |
| WARRANT #7 - SYSTEMS WARRANT | YES | NO |

| WARRANT #8 - COMBINATION OF WARRANTS | | | | |
|---|---|---|---|---|
| 80 % OF | REQUIRED | | EXISTS | |
| WARRANTS #1 & #2 | MAJOR | MINOR | MAJOR | MINOR |
| WARRANT #1 | 400 | 120 | 614 | 65 |
| WARRANT #2 | 600 | 60 | 614 | 65 |
| % OF WARRANT MET | | | 102% | 54% |

| WARRANT #9 - FOUR HOUR VOLUMES | | | | |
|---|---|---|---|---|
| | MAJOR | MINOR | CURVE NO. | WARRAN |
| 4TH HIGHEST HOUR | 740 | 80 | FIGURE | YES |
| NUMBER OF LANES | 1 | 1 | 4.7 | NO |

| WARRANT #10 - PEAK HOUR DELAY | | | | |
|---|---|---|---|---|
| PEAK HOUR: | MINOR LEG | | TOTAL ENTERING | |
| | DELAY | VOLUME | 4 LEGS | 3 LEGS |
| REQUIRED VALUES | 4 | 100 | 800 | 650 |
| EXISTING VALUES | 3 | 105 | 1150 | |

| WARRANT #11 - PEAK HOUR VOLUME | | | | |
|---|---|---|---|---|
| | MAJOR | MINOR | CURVE NO. | WARRAN |
| PEAK HOUR | 1000 | 100 | FIGURE | YES |
| NUMBER OF LANES | 1 | 1 | 4.5 | NO |

| SUMMARY OF WARRANTS SATISFIED | | | | | |
|---|---|---|---|---|---|
| WARRANT 1 | | WARRANT 5 | | WARRANT 9 | |
| WARRANT 2 | | WARRANT 6 | | WARRANT 10 | |
| WARRANT 3 | | WARRANT 7 | | WARRANT 11 | |
| WARRANT 4 | | WARRANT 8 | | TOTAL = | 0 |